Final Report

EFFECTS OF PRESCRIBED BURNING ON A SAGEBRUSH ECOSYSTEM IN NORTHWESTERN WYOMING

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Preface

This report is based on a Ph.D. thesis submitted to the Department of Zoology and Physiology and the Graduate School of the University of Wyoming. The text is divided into three major sections. Sections I and II are individual research communications written for submission to national scientific journals for publication. Section III is appendices containing supplemental data. The results presented in this document utilize data and conclusions from the final report entitled, "The Immediate Effects of Prescribed Burning on the Vertebrate Fauna in a Sagebrush-Grassland Ecosystem on Burro Hill, Teton National Forest, Wyoming," Cooperative Agreement No. 16-376-CA.

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SECTION I

AVIAN DENSITY AND DIVERSITY CHANGES FOLLOWING PRESCRIBED BURNING OF SAGEBRUSH (*ARTEMISIA TRIDENTATA*)

ABSTRACT: Avian density and diversity were estimated in two sagebrush (Artemisia tridentata) prescribed burns, one spring burn and one fall burn, and compared to estimates in a fire-suppressed ecosystem. Breeding bird density and diversity were positively correlated with increasing vegetation cover and diversity, and were directly related to the destruction of suitable nesting habitat. Non-breeding birds were inversely related to increasing vegetation structure due to more favorable hunting and foraging conditions following the removal of sagebrush and litter by the fire.

Total bird density was reduced following both burns and returned to preburn levels three years after spring burning and two years following fall burning. Total bird species diversity was significantly higher ($P < .05$) during the first postburn year on both burns, and returned to control values after two years. Seasonal changes in total diversity on both burns were due to non-breeding bird species richness.

The contribution of non-breeding birds to the total avifauna based on occurrence and abundance was highest in the early post-fire stages and decreased with time. Bird communities on the burns were less similar (based on occurrence and abundance) to avifaunas on the unburned control and became more similar with time.

This study indicates that changes in bird density and diversity following prescribed burning of sagebrush are short-lived. This suggests that the bird community in a fire suppressed mountain big sagebrush ecosystem is highly resilient to fire perturbation.

INTRODUCTION

Ecosystems in northwestern Wyoming have remained relatively unperturbed by fire for the last 70-80 years. Recently a fire management plan was implemented in the Teton wilderness allowing natural fires to burn, and similar plans are being developed for other wilderness areas in Wyoming and central Idaho (Mutch, 1976). Large portions of these areas consist of sagebrush (Artemisia tridentata) communities where natural fires frequently occur.

Prescribed burning in sagebrush is also an expanding program in this region. Burning is often used to reduce sagebrush densities, increase forage production for livestock and improve certain wildlife habitat. Plans to use prescribed fire to simulate the ecological effects of a natural fire regime in Jackson Hole are also being developed (Loope and Wood, 1974). Loope and Gruell (1973) contend that fires are necessary to maintain diversity within many ecosystems of the Jackson Hole region, and the exclusion of fire has resulted in ~~in~~de creased areas occupied by sagebrush communities.

Studies of the effects of fire in sagebrush on consumers, including both invertebrates and vertebrates, are virtually non-existent. Even for some of the more conspicuous groups like birds, the best available information on response to shrub habitat alteration come from studies on the effects of herbicides (Best, 1972; Weber, 1975; Beaver, 1976). However, bird ecology in general has been one of the most fecund in modern ecology. Many studies have demonstrated in a quantitative way that bird

density and diversity are controlled by vegetation structure (MacArthur and MacArthur, 1961; Willson, 1974; Adams and Barrett, 1976). Fewer studies have concentrated on bird populations in disturbed habitat; but Kricher (1973) did find that non-nesting birds are more abundant and diverse in early successional stages. General theory suggests that perturbations should decrease species richness with a subsequent increase as succession proceeds (Odum, 1969). However, most bird studies have failed to separate breeding from non-breeding birds or even to census non-breeders. Therefore, it is not obvious how the entire avian component, including breeders and non-breeders, responds to fire in sagebrush habitats.

This study was designed to explore the response of bird density and diversity to fire. The following hypotheses were formulated:

1. In a fire-suppressed sagebrush ecosystem total avian density and diversity are higher following prescribed burning but return to unburned levels quickly.
2. Density and diversity of breeding birds are positively correlated with increasing vegetation cover and diversity, while non-breeding birds are inversely related to increasing vegetation structure.
3. The contribution of non-breeding birds to total avifauna based on occurrence and abundance is highest in the early post-fire stages and decreases with time.

An additional objective was to assess the similarities of bird communities on spring and fall burns to those on an unburned, fire-suppressed system.

STUDY AREA AND METHODS

Description of the study area.--The study was conducted on Burro Hill, about 40 km northwest of Jackson, Teton County, Wyoming within the Bridger-Teton National Forest (Fig. 1). The elevation ranges from 2097 to 2253 m; the topography is rolling and dips gently to the northeast. Summers are typically cool (mean July temperature, 17°C) and moist (mean total June to September precipitation, 10 cm), while winters are cold (mean January low, -17°C) with snow depths frequently more than 1 m. Soils are predominantly silty loam.

On Burro Hill mountain big sagebrush (Artemisia tridentata vaseyana) (plant nomenclature follows Shaw, 1968, 1976) was the dominant shrub, forming dense, homogeneous stands with grasses and forbs present as a continuous understory. A complete list of plant species is presented in Appendix 1. Sagebrush was bordered by stands of Douglas fir (Pseudotsuga menziesii) and aspen (Populus tremuloides); each contained a characteristic avifauna (Flack, 1967).

On 3 June 1974, the U.S. Forest Service burned 15-20 ha (spring burn) on the eastern end of Burro Hill, resulting in a mosaic of patches ranging from completely burned and partially burned, to unburned. Approximately 70-80 ha, covering most of the hill, were burned on 27 August 1974 (fall burn), and all living and dead vegetation was consumed. Approximately 40-50 ha of sagebrush were left unburned along the eastern and western ends of Burro Hill.

An unburned control was established on the eastern end of Burro

Hill. Selection of the control was based upon similarity of the vegetation and bird community to the fall burn area in preburn state. No major differences in vegetative species composition, soil types (Appendix II), past fire history and grazing pressure were found. The avian community on the control showed no large differences in species composition and density from the preburn state on the fall burn.

Vegetation sampling.--The spring burn was sampled during the first (1974), second (1975) and third (1976) postburn growing seasons; the fall burn was sampled in the preburn state (1974), and during the first (1975) and second (1976) postburn growing seasons. The unburned control was sampled in all three years. Plant species composition, frequency of occurrence, and dominance (percent cover) of all vascular understory species were determined by the Daubenmire (1959) canopy-coverage method. Forty to fifty quadrats (20 x 50 cm) were distributed in a stratified random design on all study areas. Shrubs were sampled using the line intercept method (Canfield, 1941) on 10 randomly located 40-m transects. Sampling was conducted at two-week intervals, beginning the first week of June and continuing through August on all study areas. Since the bird communities were compared between areas and years, vegetation results were calculated as a mean total coverage for each species on each area in all three years; therefore, total coverage exceeds 100 percent. Total plant cover diversity (H'_p) was calculated by the Shannon-Wiener index (Shannon and Weaver, 1949): $H' = -\sum p_i \log_e p_i$ where p_i is the proportion of the total cover belonging to the i^{th} plant group (shrubs, grasses and forbs).

Bird sampling.--Permanent bird censusing plots of the following sizes were established within each burn and control area: spring burn, 10.5 ha; fall burn, 10.8 ha; unburned control, 10.0 ha. Breeding bird populations were estimated using the Williams (1936) spot-mapping technique. Non-breeding birds were counted during breeding bird censuses, and all birds were censused after the nesting season using strip transects on the permanent plots. Weekly sampling began in the first week of June and each plot was censused 8 times in 1974, 13 times in 1975, and 12 times in 1976. At each sampling time, all three plots were sampled within a two day period. Observations were made on nest site selection, clutch sizes, hatching dates and numbers fledged.

Species diversity (H') (Shannon and Weaver, 1949), species richness (S) and evenness (J') were calculated for breeding, non-breeding and total birds using total summer density estimates for each species. Also, H', S and J' for each census were calculated for the total avifauna (breeding plus non-breeding). In all calculations p_i is the proportion of individuals belonging to the i^{th} species. Since H' is sensitive to variations in both species richness (S) and evenness (J') (Pielou, 1966), these components of diversity were considered separately to avoid ambiguity in interpreting changes in bird species diversity (H'). Evenness was calculated as $J' = H'/H'_{max}$ where $H'_{max} = \log_e S$ (Pielou, 1966). Evenness is the ratio between the observed diversity H', and the maximum possible diversity for that number of species (where all species are equally abundant). Mean species diversity (H'), species richness (S) and evenness (J') values were calculated for each area in each year from the weekly sampling. Variances were tested using Cochran's Test for

Homogeneity of Variances (Dixon and Massey, 1969). Since no significance was found in any case at the 0.05 probability level, a pooled estimate of variance ($\underline{s}^2$) was calculated. All means were then tested for significance using a Least Significant Difference (LSD) value for unequal sample sizes calculated as follows:

$$LSD = t_{(1-\alpha;\ \sum(n_i-1))} \sqrt{\underline{s}^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)} .$$

If the calculated value was less than the difference of the two means, they were considered significantly different at $\alpha = 0.05$. For unequal sample sizes the LSD value was recalculated to test two unique means.

Data analysis.--The following relationships were analyzed by regression analysis (Draper and Smith, 1966): breeding, non-breeding and total bird density vs. total vegetation cover and diversity (H'_p); H' vs. S and J'; and H', S and J' vs. total vegetation cover and diversity (H'_p).

Importance values (IV) were calculated using summer totals for each bird species per study area per year to evaluate the contribution of non-breeding birds to the total avifauna, and to assess similarity between bird communities (Kricher, 1973). The IV was calculated as the relative density plus the relative frequency (percent of the total number of censuses on which a given species appeared) (Kricher, 1973). Similarity was determined using the coefficient of community:

$$C = \frac{2w}{a+b}$$

where w = the sum of the lower of two IV's for species shared by two study areas a = the sum of all IV's for Area A, and b = the sum of all

IV's for Area B (Bray and Curtis, 1957).

RESULTS

Changes in vegetation.--Changes in dominance (percent cover) and cover diversity (H'_p) of the vegetative groups are shown in Table 1. The fall burn destroyed almost 100 percent of the shrubs, whereas the spring burn resulted in areas of complete, partial and no kill. Although shrub coverage was reduced markedly on both burns, it increased steadily during the succeeding years. Most species of shrubs resprouted readily; but sagebrush was slower because it re-establishes solely by seed.

The patchy spring burn resulted from a less intense fire, characteristic of spring burns in this region. In the early spring, fine fuel loads (grass, forbs and litter) were relatively low and discontinuous; fire did not carry well between sagebrush concentrations, resulting in cooler fires and more patchy burns with many areas containing standing snags. In contrast, the fall burn reduced cover more effectively, leaving vast stretches of bare ground covered with ash. At the end of the growing season fine fuel loads were higher and supported a much hotter fire. Consequently, the fire carried well and was similar in intensity to wildfire in this region.

Coverage and frequency of grasses (and grass-like plants) changed dramatically on both burns. In the first postburn season, cover on the spring burn was 50 percent lower than the unburned control, while cover on the fall burn site was 82 percent lower than preburn levels. At the end of the third postburn season on the spring burn, grass cover was 79 percent of the unburned control level. Grass cover on the fall burn

increased two-and-a-half fold during the second postburn season to 54 percent of the control value.

Both spring and fall burns reduced forb coverage, but after two postburn growing seasons, forb coverage was at or above preburn and unburned levels. Forbs and grasses grew vigorously following burning. In most cases, the increase in coverage was not accompanied by a corresponding increase in frequency, indicating that fewer, but larger individuals were contributing more coverage. The contribution of grasses relative to forbs was altered more dramatically on the fall burn with forbs contributing more to total coverage in both postburn seasons.

Diversity of vegetative cover (H'_p) on the control remained relatively unchanged in the three years of study. Both spring and fall burning reduced diversity with the largest decrease occurring on the fall burn. Diversity on the spring burn was reduced slightly in the first postburn year and returned to control levels three years following the burn. In contrast, H'_p was reduced greatly following fall burning and remained low two years after burning.

Breeding bird density.--Nine species of birds bred on the study areas during the three years of censusing. However, only four species nested in all three years: two sparrows, a towhee and the blue grouse (Table 2).

Density trends on the control, and one year preburn on the fall burn plot, differed little among years other than a slight increase in 1976. This increase in density was due to the Brewer's Sparrow which is locally common but not abundant in the Jackson Hole region. On the

control plots, most of the increase in density due to Brewer's Sparrow was offset by decreases in Green-tailed Towhee and White-crowned Sparrow densities (Table 2).

Breeding bird density on the spring burn in the first postburn year was 61 percent lower than the control. Density on the burn increased steadily in the second and third postburn years and was 31 percent below control density three years after burning. In the earliest successional years breeding birds used the standing snags of burned sagebrush plants as song perches in territory establishment. However, nests were placed in unburned patches, while breeding birds foraged the burned ground.

Breeding bird density on the fall burn was drastically reduced. In the first postburn breeding season (1975), no birds bred on the area, since there was no suitable habitat for breeding. Species that bred on the area prior to burning in 1974 were present on the plot in 1975 and 1976, but were categorized as non-breeding. These individuals were observed foraging on the burn area and flying towards the spring burn and the unburned sagebrush.

In the second postburn season, breeding bird density on the fall burn increased to 28 percent of the density estimated on the unburned plots. This increase was due to the Brewer's Sparrow which selected nest sites in large sticky geranium (Geranium viscosissimum) and yarrow (Achillea millefolium) plants; no nests were found on the ground. These plants grew to much larger size resembling the shrub life form rather than being forb-like.

Non-breeding bird density.--In contrast to breeding birds, non-breeding bird densities increased in the first postburn season on both spring and

fall burns (Table 3). Density on the spring burn in the first postburn year was 73 percent higher than observed on the unburned control plots. This density decreased in the second year postburn, and was almost equal to the density on the unburned plots three years after burning.

The change in non-breeding bird density was most dramatic on the fall burn in 1975. Density increased more than six-fold from preburn levels during the first postburn growing season. In all cases, numbers of non-breeding species increased. In contrast, species that bred on the plot before the burn reappeared in the postburn years as non-breeders but at lower densities.

Both burns resulted in open areas which the non-breeding birds used for hunting and foraging, some within minutes after the fire. Small mammal densities were high on the fall burn in both postburn years. Raptorial birds were observed catching these rodents in both years. The elimination of the previously dense sagebrush may have improved hunting success by these raptors. As these burned areas became revegetated during succession, open-ground foraging and hunting were excluded and non-breeding bird densities decreased.

The contribution of non-breeding birds to the total avifauna was further evaluated by calculating importance values for all species (Table 4). Figure 2 summarizes these data by presenting the proportion of non-breeding species relative to the entire avifauna on all study areas in the three years of the study. Non-breeding species contributed most on the fall burn, and moderately so on the spring burn. Three years following spring burning, their contribution had declined to a value near that for the unburned plots. Their contribution on the fall burn was

still high after two postburn seasons, but had declined considerably from the first postburn season values.

Total bird density.--In 1974 the total density of birds on the spring burn was 34 percent lower than observed on the control. Also, it was 25 percent lower than the density on the fall burn plot in preburn state (Table 5). This density increased 16 percent and 17 percent in the second and third years postburn, respectively, but after three years was 29 percent lower than the control density. Total bird density in the first postburn year on the fall burn decreased 20 percent from preburn levels. Total density returned to preburn density after two years, but was also below unburned density.

Comparing each burn area after its first postburn season (Spring 1974 and Fall 1975) the total avifauna differed by only 10.8 individuals, the fall burn being slightly higher. However, the ratio of breeding to non-breeding birds differed greatly on the two burns (Fig. 2). Three years after spring burning, and two years after fall burning, total densities were essentially equal but still lower than unburned values. Therefore, the analysis of the total avifauna without distinguishing between breeding or non-breeding, can be misleading.

Avian density in relation to vegetation changes.--Regression analysis indicates that breeding bird density was significantly and positively correlated with percent total vegetation cover and diversity (H'_p) (Figs. 3 and 4). The majority of species breeding on Burro Hill nested in shrubs or on the ground, and in the earliest fire-successional stages both cover and diversity of cover were low. With time, however, both

cover and diversity increased providing more suitable conditions for nesting and breeding bird density increased.

Non-breeding bird density was significantly, but inversely, correlated with total cover and H'_p. Total bird density was highly positively correlated with total plant cover but not significantly correlated with H'_p (Figs. 3 and 4). In the earliest and most fire damaged seres, non-breeding birds contributed heaviest to the total density; and this contribution decreased with time after the fire. Breeding birds became dominant soon after burning and far outweighed non-breeding birds in the second and third postburn years. Therefore, total avian density reflects the increasing contribution of breeding bird numbers with time, while the inverse response of non-breeding birds to total cover and diversity further emphasizes their decreasing contribution to total density in later successional stages.

Bird species diversity in relation to vegetation changes.--Species diversity (H'), species richness (S) and evenness (J') estimates were calculated for breeding, non-breeding and total birds using total summer estimates for each species (Table 6). Breeding bird H', S and J' were significantly and positively correlated to changes in plant cover diversity, H'_p (Table 7). Apparently breeding birds responded to the variety of vegetation cover available since H'_p measures the diversity of the shrub, grass and forb categories. However, H' and S were also significantly correlated with percent total cover indicating that as the diversity of cover and amount of suitable nesting habitat increased in the postburn stages, breeding bird diversity and species richness also increased.

Diversity, ln S and J' for non-breeding birds were significantly related to cover and diversity in a similar though inverse pattern to breeding birds. However, non-breeding H' was more significantly correlated to total cover than were breeding birds. Non-breeding birds utilized the early successional areas for foraging and hunting since the removal of cover presumably increased the availability of food, but they selected nesting sites in the surrounding habitat. Breeding birds responded more to changes in vegetation variety while non-breeding birds reacted to changes in both variety and total cover.

Total bird H' and J' were significantly and inversely correlated with both total cover and diversity but total species richess (S) showed no significant relationship with either vegetative parameter (Table 7). These inverse correlations for total birds reflect the trends of non-breeding birds. Apparently the total bird community reflects the non-breeding more than the breeding component; a reasonable assumption since the non-breeding birds were abundant and frequent in the earliest successional stages.

Seasonal changes in H', S and J'.--Bird species diversity (H') calculated from each census is plotted against sampling data in Fig. 5. The unburned control and the fall preburn (1974) showed a relatively constant pattern throughout the summer. After burning, H' varied more between samplings (Fig. 5), but tended to become less variable with each succeeding postburn year.

A mean H' over all samplings for each year was calculated and on the unburned plots did not change significantly ($P > 0.05$) during the three

years of the study (Table 8). Both burns had significantly ($P < 0.05$) higher mean H' values in the first year postburn compared to the unburned control in the same year (Tables 8 and 9). Three years after spring burning and two years after fall burning, mean H' was essentially equal on all areas. However, H' on the spring burn had returned to unburned control levels after two years. Therefore, two years after spring or fall burning, H' had returned to unburned levels, and the two burns had equal mean H' values. The highest H'_s value occurred on the spring burn during its first postburn season. Although mean H' on the fall burn in its first postburn year was lower than the spring burn value in 1974, they were not statistically different ($P > 0.05$).

Changes in species richness (S) over sampling times exhibited patterns similar to H' (Fig. 6). Species richness over the summer remained relatively constant on the unburned control (1974-76) and on the fall preburn (1974). Similar to H', after burning S fluctuated more between sampling times, but with the amplitude decreasing with each succeeding postburn year.

The lowest mean S calculated from each summer's samples was on the fall burn in preburn state (Table 8), but it was not statistically different from the unburned control (Table 9). The highest value was observed on the fall burn in its first season postburn which was significantly ($P < 0.05$) different from the control in 1975, and the preburn value. The spring burn also had a significantly higher mean S in its first postburn year. As with H' after two postburn seasons, mean S on both burns was not different from the unburned control values, nor were they different from each other ($P > 0.05$). Richness on the unburned-control

did not change significantly during all three years.

Changes in relative abundance or evenness (J') on the fall burn were decidedly different from the pattern on the spring burn (Fig. 7). Evenness on the spring burn remained high and relatively constant within and between years. On the fall burn, the first postburn season exhibited the most variation in J', but resembled preburn patterns the following summer. Evenness on the control showed considerable fluctuation, particularly in 1975.

Mean J' decreased slightly during the three postburn years on the spring burn (Table 8). Compared to the unburned control within the same year, mean J' was significantly higher ($P < 0.05$) on the spring burn in its first two postburn years. On the fall burn mean J' decreased the first year after burning; however, it increased significantly ($P < 0.05$) during the second postburn season. No significant differences in mean J' were observed between the fall burn and unburned control within the same years. Evenness varied slightly on the unburned control in all three years.

Effect of S and J' on H'.--Regression analysis indicates that S had a highly significant ($P < 0.005$) effect on total H' on both burn areas in all postburn years (Table 10). Also, the lower coefficients of variation found for evenness and consistently high values for S (Table 8) further indicate that most of the variations in H' were due to differing S. The unburned control showed different effects of the components on H'. In 1975 it appears that J' had more influence on H', as H' and J' decreased while S increased. But in 1976, H', S and J' increased, and the effect of S on H', although significant ($P < 0.05$) was less than in

1974.

Similarity of avian communities.--The coefficient of community was used to compare the bird communities on the burn areas to the unburned control in the same year (Table 11). Bird communities on both burns in the first year postburn were less similar to the control in the same year. Avian communities on the burned areas became more similar to the avifauna on the unburned control in succeeding years (e.g., see outlined sequences in Table 11). Three seasons following spring burning, the burn and unburned control were 89 percent similar, while the fall burn was 76 percent similar to the unburned control after two years.

DISCUSSION

The most obvious reason for the decline in breeding bird density immediately following burning is the destruction of suitable nesting habitat. The fall burn destroyed all available nest sites, whereas the spring fire left suitable areas of unburned sagebrush. Nesting by passerines was not observed in areas where the fire burned most intensely. Blue Grouse males did use the intense burns for courtship display, but they nested only in the unburned and partially burned patches.

Completely burned areas of bare soil on the spring burn were used exclusively for foraging by breeding passerines. With revegetation, breeding species began nesting and their densities increased. Lack (1933) was the first to show that on successional areas where rapid revegetation is occurring, a drastic change in avifauna can occur in a relatively short time (Balda, 1975). Lack contended that suitable nesting requirements and a correct set of "psychological characters" were the two most important factors for successful nesting. Breeding birds on Burro Hill apparently responded similarly.

On the fall burn no birds bred since all nest sites were destroyed. Two years after burning only one species nested using large forbs rather than shrubs.

Although food availability was not directly measured in this study, the increases in non-breeding birds on burned areas are most logically explained by an increased availability of food and/or increased ease of foraging. Chaparral fire concentrates seeds of shrub and grass

vegetation on the soil surface (Lawrence, 1966) and seeds are readily available on burned ground (Sweeney, 1956). Lawrence (1966) concluded that increased densities of birds on his experimental plots were directly correlated with resulting concentrations of food. Insects on the soil surface are also known to be high following chaparral fires (Lawrence, 1966). Stoddard (1963) also stated that availability of food attracts birds to burned areas. The burning of vegetation and litter exposed seeds and insects making them far more susceptible to foraging birds. The spring burn provided many snags from which birds could locate and capture prey. As these areas became revegetated, providing dense cover to the prey, foraging and hunting was less favorable and non-breeding bird densities decreased. The contribution of non-breeding birds to the total avifauna was most dramatic on the fall burn since previously breeding species were reclassified as non-breeding. Both burns caused non-breeding birds to contribute more to the total avifauna immediately after burning and this contribution decreased with time.

An important characteristic of the bird populations on Burro Hill was the presence of mixed species flocks of non-breeding birds. Kricher (1972) has stated that their presence is responsible for (1) an overall decrease in the mean J', and (2) a great increase in variability of S and J'. He further reports that these flocks were large (often exceeding 100 individuals) and sporadic on his early old-field successional plots, accounting for low equitability. On the Burro Hill unburned control non-breeding bird flocks were relatively small (usually less than ten individuals) and unpredictable. On the seccessional stage following

spring burning, these flocks were consistently present and usually larger, about 20 to 30 individuals. Therefore, J' values would be expected to be lower but they were significantly ($P < 0.05$) higher than observed on the unburned control due to the presence of breeding birds.

On the fall burn immediately following burning, all species were classified as non-breeding and flocks tended to be large (more than 50 individuals) and sporadic over the entire plot. This was reflected in J' values lower than the preburn, consistent with Kricher's (1972) observations. However, in the second postburn year flocks were much smaller and breeding birds were present, resulting in an increase in J'. Variability trends agreed with Kricher's observations, i.e., higher when J' was low, and lower when J' was high.

Margalef (1963) has suggested that animals in more mature communities often exploit the products (food in the form of seeds and foliage) of less mature communities, while nesting and reproducing in the more mature communities. The non-breeding birds on Burro Hill responded in a similar manner; the majority (81%) of non-breeding species were known to be nesting in the adjacent communities.

Tramer (1969) showed breeding bird species diversity (H') was highly correlated with species richness (S), and that relative abundance (J') was stable in his samples. Kricher (1972) examined nesting and non-nesting species on different old-field seral stages in New Jersey and found S to account for many differences in total bird species diversity between

stages. He also found that J' had its greatest influence on H' in its earliest successional stage due mainly to non-nesting species. On the spring burn plot on Burro Hill, both S and J' influenced H'. On the fall burn plot, S had a greater influence on H'. Non-breeding species accounted for these effects and differences. In the fire-suppressed sagebrush neither S nor J' influenced H' consistently. Both components affected H' in different years and non-breeding species had little to do with these differences. These results indicate that in ecosystems where most species are breeders, species richness can be an accurate predictor of H'; however, in fire-successional sagebrush ecosystems, the contribution of the non-breeding component must be considered if the true total avian community is to be described.

A major objective of this study was to determine if bird density, diversity, species richness and evenness were related to changes in vegetation structure. Tramer (1969) has suggested that changes in the avian community are due largely to changes in layering of the plant community. Roth (1976) reports that new patches in an ecosystem result from the addition of layers of vegetation and that increased heterogeneity is positively correlated with bird species diversity. In my study highly significant ($P < 0.05$) correlations were found for breeding and non-breeding density, diversity and species richness, versus total vegetation cover and diversity (H'_p). Birds responded to overall structure of the sagebrush community and changed predictably following alteration by fire. MacArthur and MacArthur (1961) and Willson (1974) also showed bird species diversity to be correlated with vegetation (foliage height) diversity.

Usually the earliest seral stages are structurally the simplest

while the climax is the most complex (Odum, 1969). The unburned sagebrush on Burro Hill had been unperturbed by fire for a sufficient time to be regarded as a more or less steady-state climax community. It was stratified into two distinct layers, a canopy dominated primarily by sagebrush and a ground layer consisting of grasses and forbs. This unburned ecosystem was structurally more complex than the early successional stages on each burn.

Kricher (1973) contends that bird species diversity (H') is most variable in a less complex and perhaps, less stable ecosystem. Total bird species diversity (H') in the more complex unburned sagebrush on Burro Hill showed relatively stable trends, while in the earliest fire-successional stages H' increased and was more variable, consistent with Kricher's contention. The magnitude of increase was significant on both burns in the first postburn years, but this increase was of short duration. Two years after burning (spring or fall) H' returned to unburned levels. Kricher (1973) further contends that the degree of instability, as measured by the rapidity of change in the biotic components, decreases steadily with succession. Data presented here support this contention. The earliest fire-successional bird communities are relatively unstable, and steadily become more stable.

The large increase in H' immediately following sagebrush burning resulted from the influence of non-breeding birds. The number of species and abundance of these birds increased dramatically after burning, and their contribution to total avian density was highest immediately after burning and decreased steadily. Kricher (1973) also suggests that the percentage of nesting birds to total bird species found in the ecosystem

will be lower in a more unstable ecosystem. My data are consistent with this hypothesis.

The seasonal trends in S and J' can also be attributed to non-breeding birds. Significant increases in mean S were due to the influx of non-breeding species from surrounding habitat to hunt and feed on the burned areas. Many of the species were present in the unburned sagebrush, but at low frequencies and abundance, whereas after burning they increased in density and occurrence.

In summary, results of this study support the hypothesis that the bird community in a fire suppressed mountain big sagebrush ecosystem is highly resilient to fire perturbation. Following prescribed burning, total bird density is reduced and diversity increased, but they returned to climax values quickly. Breeding bird density and diversity were reduced immediately following burning and were positively correlated with changes in vegetation diversity. Non-breeding birds were inversely related to increasing vegetation cover and diversity, and their contribution to total bird density and diversity was highest in the early post-fire stages and decreased with time.

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Table 1. Dominance (percent cover) and diversity (H'_p) of major plant groups on Burro Hill study areas. (See Appendix III for breakdown by species.)

Plant Group	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Preburn	Postburn	
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Shrubs	50	49	48	10	15	19	48	3	9
Grasses and grass-like plants	27	30	28	14	19	22	33	6	15
Forbs	30	35	41	26	32	31	40	15	44
Total Cover	107	114	117	50	66	72	121	24	68
Total cover diversity (H'_p)	1.06	1.08	1.08	1.02	1.05	1.08	1.07	0.90	0.88

Table 2. Breeding bird densities (pairs/40 ha) on Burro Hill study areas.

	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-burn	Postburn	
Species	1974	1975	1976	1974	1975	1976	1974	1975	1976
Green-tailed Towhee	32.0	30.0	18.0	11.6	21.9	15.0	34.3	--	--
Vesper Sparrow	10.0	12.1	12.8	3.9	11.5	10.6	11.2	--	--
White-crowned Sparrow	20.0	22.0	15.0	3.9	5.7	9.8	16.7	--	--
Blue Grouse	8.0	16.0	11.5	11.6	11.6	12.7	11.2	--	--
Western Meadowlark	4.1	--	--	--	--	--	3.8	--	--
Chipping Sparrow	4.1	--	--	--	--	--	--	--	--
Mourning Dove	--	--	4.0	--	--	3.8	--	--	--
Brewer's Sparrow	--	--	26.1	--	--	15.0	--	--	25.6
American Robin	--	--	4.0	--	--	--	--	--	--
Totals	78.2	80.1	91.4	31.0	50.7	66.9	77.2	0	25.6

See Appendix IV for complete list of birds.

Table 3. Non-breeding bird densities (individuals/40 ha) on Burro Hill study areas.

Species	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-Burn	Postburn	
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Red-tailed Hawk	0.5	0.3	0.2	0.6	0.3	0.0	0.5	3.5	0.2
Swainson's Hawk	0.0	0.0	0.6	0.0	0.0	1.5	0.0	1.9	2.0
Marsh Hawk	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.6	0.2
Sparrow Hawk	2.6	0.3	1.1	4.7	1.0	0.5	0.5	3.5	1.8
Blue Grouse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	7.0
Sandhill Crane	0.0	0.0	0.2	1.9	2.5	0.7	0.0	5.5	2.1
Mourning Dove	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.7
Common Flicker	2.0	3.0	3.7	9.6	4.7	2.1	0.9	7.1	2.7
Hairy Woodpecker	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.2
Tree Swallow	11.6	4.5	14.2	14.3	10.2	14.6	6.0	13.2	16.7
Barn Swallow	4.5	3.0	2.2	5.2	9.2	3.8	3.3	10.2	5.7
American Robin	1.5	2.0	0.0	8.1	2.2	1.7	1.9	5.8	2.1
Mountain Bluebird	3.0	2.0	2.7	8.1	6.7	2.4	2.8	17.0	9.9
Yellow-rumped Warbler	1.0	0.3	0.4	4.4	4.2	1.0	0.9	15.1	1.5
Western Meadowlark	0.0	0.0	2.4	0.0	0.0	2.5	0.0	0.0	1.5
Brewer's Blackbird	9.0	5.3	6.9	4.7	3.9	2.9	0.0	4.9	0.0
Western Tanager	0.0	0.0	0.2	0.6	1.6	0.5	0.0	0.3	0.2
Pine Siskin	0.0	0.0	0.2	0.0	0.0	1.7	0.9	1.2	9.8
Green-tailed Towhee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	6.9
Vesper Sparrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	10.0
Dark-eyed Junco	3.0	3.0	1.8	4.7	1.6	4.7	1.4	6.2	1.5
White-crowned Sparrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6	15.3
Totals	38.7	23.7	37.0	66.9	48.1	40.6	19.1	138.1	122.0

Table 4. Avian importance values (relative density + relative frequency X 100) on Burro Hill study areas, 1974-1976, * = breeding species. Species listed are those with $\geq$ 5 sightings during the study period.

Species	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-Burn	Postburn	
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Red-tailed Hawk	2.8	1.3	0.8	2.6	1.7	--	3.2	8.2	2.2
Swainson's Hawk	--	--	7.1	--	--	7.9	--	7.7	6.8
Marsh Hawk	--	--	1.5	--	--	--	--	4.7	1.5
Sparrow Hawk	5.1	2.3	2.5	9.9	3.0	1.7	1.7	6.0	2.4
Blue Grouse	18.3*	31.1*	18.7*	26.4*	25.3*	23.1*	24.5*	9.5	12.4
Sandhill Crane	--	--	2.1	5.7	4.0	1.8	--	8.6	3.3
Mourning Dove	--	--	10.4*	--	--	10.0	--	--	21.8
Common Flicker	4.8	4.8	4.4	13.7	7.6	4.0	3.4	11.4	4.4
Hairy Woodpecker	--	--	--	--	--	--	--	3.7	1.5
Tree Swallow	16.0	14.0	14.7	19.5	15.9	16.9	12.2	17.1	18.0
Barn Swallow	7.4	10.0	7.1	11.4	14.5	8.5	7.7	14.9	9.9
American Robin	4.6	4.3	9.0*	12.6	4.5	3.8	8.3	9.4	4.7
Mountain Bluebird	6.6	4.3	5.3	14.7	12.8	4.2	7.4	18.6	12.7
Yellow-rumped Warbler	3.0	1.3	1.6	8.7	7.3	2.7	3.4	17.2	3.0
Western Meadowlark	9.3*	--	2.5	--	--	6.3	13.1*	--	2.3
Brewer's Blackbird	12.2	6.1	7.2	8.9	7.9	3.8	--	8.1	--
Western Tanager	--	--	0.8	2.6	7.2	1.7	--	1.5	1.5
Pine Siskin	--	--	1.5	--	--	5.2	3.4	3.2	11.3
Green-tailed Towhee	42.9*	46.3*	24.6*	26.4*	39.1*	25.7*	51.1*	12.3	9.6
Vesper Sparrow	20.4*	26.9*	19.8*	14.5*	25.2*	20.7*	24.5*	10.0	12.8
Dark-eyed Junco	4.0	10.0	4.9	7.8	6.4	6.9	5.1	8.5	3.0
Chipping Sparrow	11.8*	--	--	--	--	--	--	--	--
Brewer's Sparrow	--	--	31.9*	--	--	25.7*	--	--	38.0*
White-crowned Sparrow	30.6*	37.6*	21.8*	14.5*	17.4*	19.7*	30.9*	19.0	16.5

Table 5. Total avian densities (individuals/40 ha) on Burro Hill study areas.

	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-Burn	Postburn	
Category	1974	1975	1976	1974	1975	1976	1974	1975	1976
Breeding	156.4	160.2	182.8	62.0	101.4	133.8	154.4	0	51.2
Non-Breeding	38.7	23.7	37.0	66.9	48.1	40.6	19.1	138.1	122.0
Total	195.1	183.9	219.8	128.9	149.5	174.4	173.5	138.1	173.2

Table 6. Breeding, non-breeding and total bird species diversity (H'), species richness (S) and evenness (J') values for Burro Hill study areas. Calculations are based upon total summer census.

		Unburned Control			Spring Burn			Fall Burn		
					Postburn			Pre-Burn	Postburn	
		1974	1975	1976	1974	1975	1976	1974	1975	1976
Breeding Birds	H'	1.51	1.33	1.80	1.26	1.29	1.73	1.40	0	0
	S	6	4	7	4	4	6	5	0	1
	J'	0.84	0.96	0.93	0.91	0.93	0.97	0.87	0	0
Non-breeding Birds	H'	1.96	2.02	1.96	2.24	2.18	2.16	1.99	2.72	2.51
	S	10	10	15	12	12	14	10	20	21
	J'	0.85	0.88	0.72	0.90	0.88	0.82	0.86	0.91	0.82
Total Birds	H'	2.11	1.80	2.27	2.46	2.21	2.37	1.81	2.72	2.45
	S	16	14	22	16	16	20	15	20	22
	J'	0.76	0.68	0.73	0.89	0.80	0.79	0.67	0.91	0.79

Table 7. Regression equations and correlation coefficients (r) (95% confidence limits in parentheses) for breeding, non-breeding and total H', $\log_e$ S and J' against percent total cover (top) and total vegetation cover diversity (H'_p) (bottom); P is the probability of obtaining the r value if there was no correlation.

	H'	$\log_e$ S	J'
Percent Total Cover			
Breeding Birds	Y = 0.10 + 0.01 X r = 0.64 (-0.06, 0.89) P < 0.05	Y = 0.07 + 0.01 X r = 0.66 (0.04, 0.90) P < 0.05	Y = 0.15 + 0.01 X r = 0.58 (-0.15, 0.88) P > 0.05
Non-Breeding Birds	Y = 2.75 - 0.01 X r = -0.88 (-0.91, -0.52) P < 0.005	Y = 3.01 - 0.01 X r = -0.62 (-0.89, 0.10) P < 0.05	Y = 0.92 - 0.0008 X r = -0.51 (-0.86, 0.24) P > 0.05
Total Birds	Y = 2.88 - 0.01 X r = -0.86 (-0.93, -0.42) P ≤ 0.005	Y = 3.00 - 0.001 X r = -0.33 (-0.79, 0.40) P ≥ 0.05	Y = 0.97 - 0.002 X r = -0.95 (-0.99, -0.79) P ≤ 0.0005
Total Cover Diversity			
Breeding Birds	Y = -7.42 + 8.36 X r = 0.97 (0.82, 0.98) P < 0.0005	Y = -8.06 + 9.09 X r = 0.97 (0.82, 0.98) P < 0.0005	Y = -4.41 + 5.00 X r = 0.97 (0.82, 0.98) P < 0.0005
Non-Breeding Birds	Y = 5.37 - 3.10 X r = -0.92 (-0.98, -0.63) P < 0.0005	Y = 5.65 - 2.99 X r = -0.82 (-0.96, -0.30) P < 0.005	Y = 1.04 - 0.19 X r = -0.26 (-0.72, 0.53) P > 0.05
Total Birds	Y = 4.96 - 2.65 X r = -0.69 (-0.92, -0.04) P < 0.025	Y = 3.99 - 1.09 X r = -0.50 (-0.85, 0.25) P > 0.05	Y = 1.42 - 0.63 X r = -0.60 (-0.88, 0.10) P < 0.025

Table 8. Average total bird species diversity (H'), species richness (S) and evenness (J') $\pm$ one standard error. Numbers in parentheses are coefficients of variation. In 1974, n = 8; in 1975, n = 13; in 1976, n = 12.

	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-burn	Postburn	
	1974	1975	1976	1974	1975	1976	1974	1975	1976
H'	1.91 ± 0.07 (11%)	1.83 ± 0.06 (11%)	2.05 ± 0.07 (12%)	2.35 ± 0.12 (14%)	2.00 ± 0.07 (13%)	2.03 ± 0.07 (11%)	1.76 ± 0.03 (5%)	2.15 ± 0.11 (19%)	2.01 ± 0.07 (11%)
S-	9.2 + 0.7 (21%)	9.4 ± 0.3 (13%)	10.0 ± 0.4 (16%)	12.4 ± 1.0 (23%)	9.0 ± 0.7 (30%)	9.3 ± 0.5 (18%)	7.2 ± 0.5 (22%)	13.2 ± 1.0 (17%)	9.0 ± 0.4 (17%)
J'	0.87 ± 0.02 (6%)	0.82 ± 0.03 (15%)	0.89 ± 0.02 (9%)	0.94 ± 0.05 (6%)	0.93 ± 0.05 (5%)	0.91 ± 0.05 (6%)	0.90 ± 0.02 (7%)	0.83 ± 0.04 (16%)	0.92 ± 0.02 (8%)

Table 9. Ranked total species diversity (H'), species richness (S), and evenness (J') means for all study areas in all years. Means which are connected by underline are not significantly different at probability 0.05 using Least Significant Difference analysis for unequal sample sizes.

Study area and year[1]	F74	U75	U74	S75	F76	S76	U76	F75	S74
Species diversity (H')	1.76	1.83	1.91	2.00	2.01	2.03	2.05	2.15	2.35

Study area and year	F74	S75	F76	U74	S76	U75	U76	S74	F75
Species richness (S)	7.2	9.0	9.0	9.2	9.3	9.4	10.0	12.4	13.2

Study area and year	U75	F75	U74	U76	F74	S76	F76	S75	S74
Evenness (J')	0.82	0.83	0.87	0.89	0.90	0.91	0.92	0.93	0.94

[1] F = Fall Burn, S = Spring Burn, U = Unburned Control. Example: F74 = Fall Burn 1974.

Table 10. Correlation coefficients (r) and sample sizes for the regression of total species diversity (H') against the natural logarithm of the number of species ($\log_e S$).

Study Area	Year	Sample Size	r
Spring Burn	1974	8	0.950**
	1975	13	0.944**
	1976	12	0.803**
Fall Burn	1974	8	0.913**
	1975	13	0.791**
	1976	12	0.718**
Unburned-Control	1974	8	0.836**
	1975	13	-0.310
	1976	12	0.633*

*Significantly non-zero at 0.05 level.

**Significantly non-zero at 0.005 level.

Table 11. Coefficients of community for Burro Hill study areas, 1974-1976. Values indicate degree of similarity in community composition between study areas in all years. Coefficients were calculated using importance values.

		Spring Burn			Fall Burn			Unburned-Control		
		1974	1975	1976	1974	1975	1976	1974	1975	1976
Spring Burn	1974	--								
	1975	0.83	--							
	1976	0.67	0.71	--						
Fall Burn	1974	0.66	0.76	0.70	--					
	1975	0.75	0.68	0.59	0.53	--				
	1976	0.57	0.57	0.75	0.51	0.62	--			
Unburned-Control	1974	0.68	0.77	0.69	0.83	0.57	0.52	--		
	1975	0.69	0.81	0.69	0.84	0.54	0.48	0.70	--	
	1976	0.66	0.68	0.89	0.67	0.61	0.76	0.70	0.67	--

Fig. 1. Burro Hill study area on Bridger-Teton National Forest.

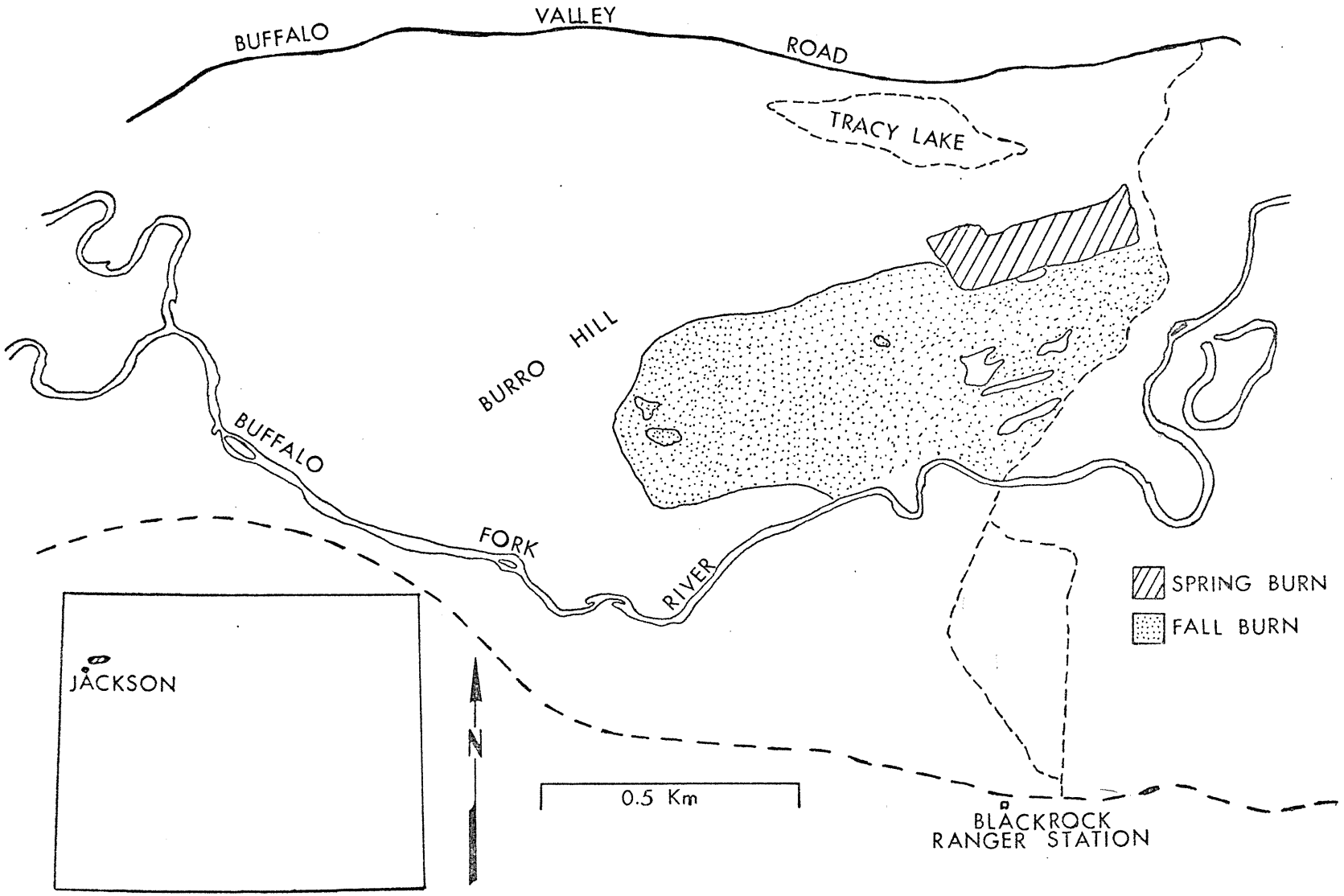

BUFFALO VALLEY ROAD
TRACY LAKE
BURRO HILL
BUFFALO FORK RIVER
SPRING BURN
FALL BURN
JACKSON
N
0.5 Km
BLACKROCK RANGER STATION

Fig. 2. Contribution of non-breeding birds to the total avifauna on Burro Hill study areas.

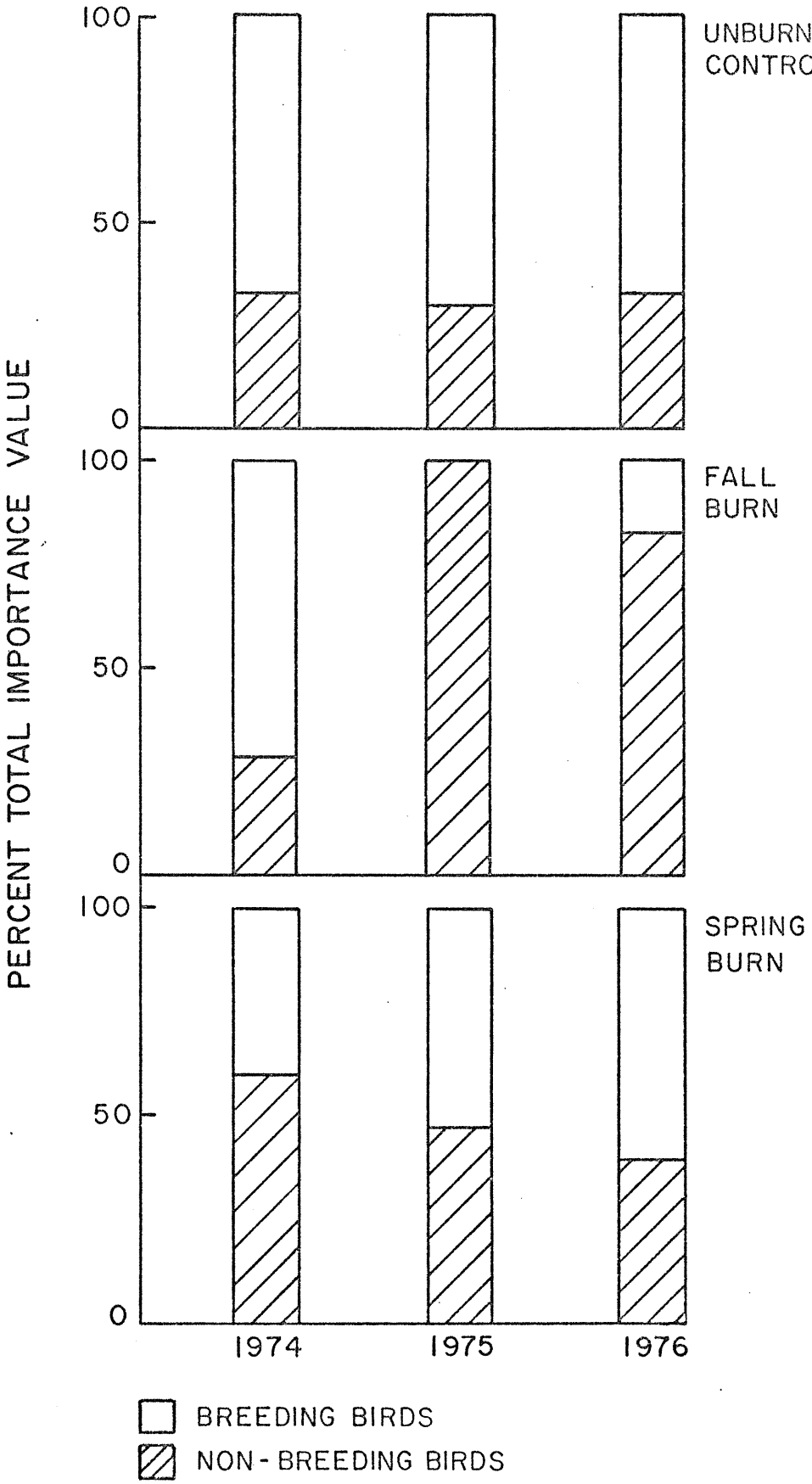

PERCENT TOTAL IMPORTANCE VALUE
100
50
0
UNBURNED CONTROL
FALL BURN
SPRING BURN
1974
1975
1976
BREEDING BIRDS
NON-BREEDING BIRDS

Fig. 3. Regressions of breeding, non-breeding and total densities on percent total cover; 95% confidence limits for r are in parentheses.

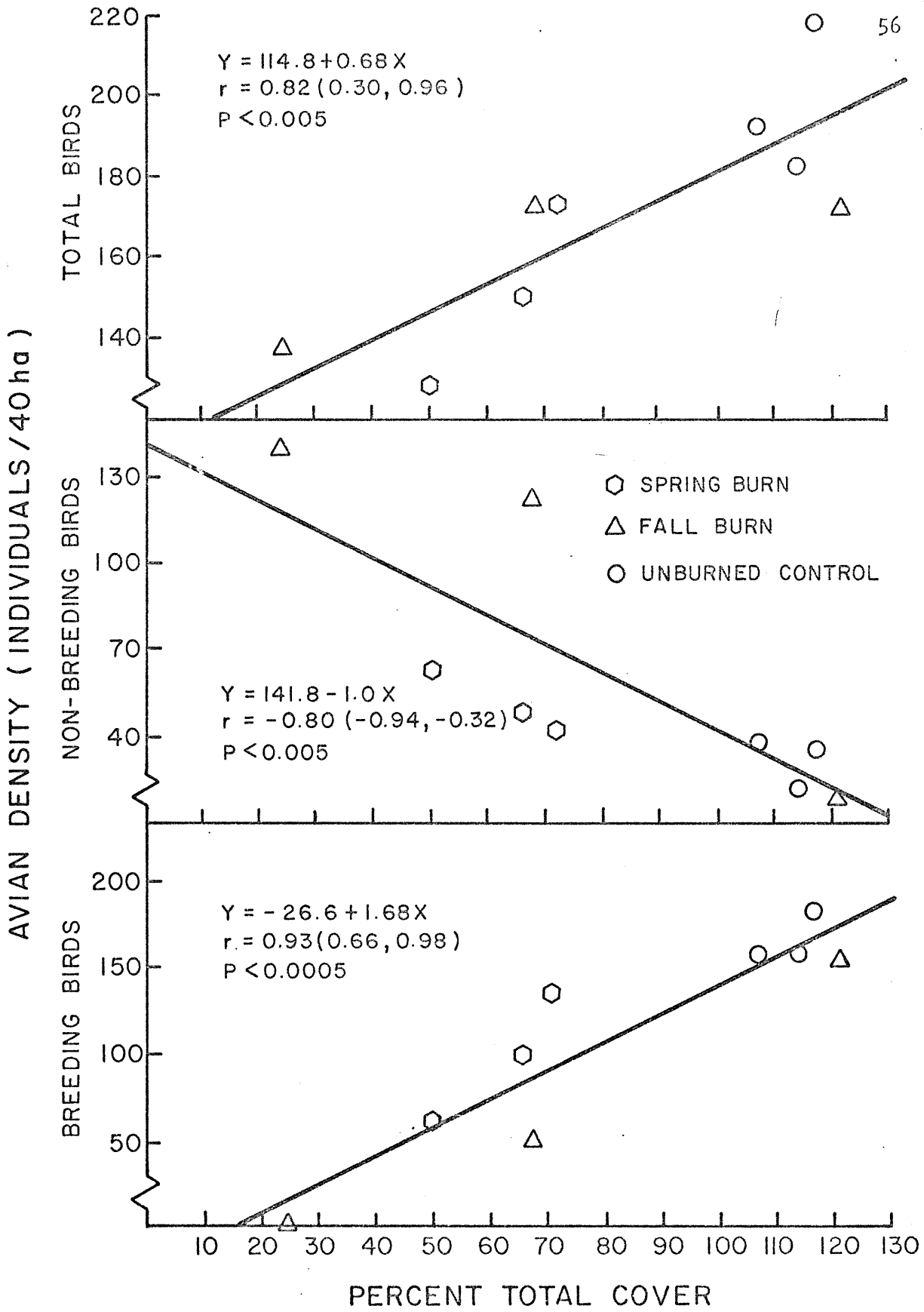

AVIAN DENSITY (INDIVIDUALS/40 ha)
TOTAL BIRDS
Y = 114.8+0.68X
r = 0.82 (0.30, 0.96)
P < 0.005
NON-BREEDING BIRDS
Y = 141.8 - 1.0X
r = -0.80 (-0.94, -0.32)
P < 0.005
BREEDING BIRDS
Y = -26.6 + 1.68X
r = 0.93 (0.66, 0.98)
P < 0.0005
SPRING BURN
FALL BURN
UNBURNED CONTROL
PERCENT TOTAL COVER

Fig. 4. Regressions of breeding, non-breeding and total densities on plant cover diversity (H'_p); 95% confidence limits for r are in parentheses.

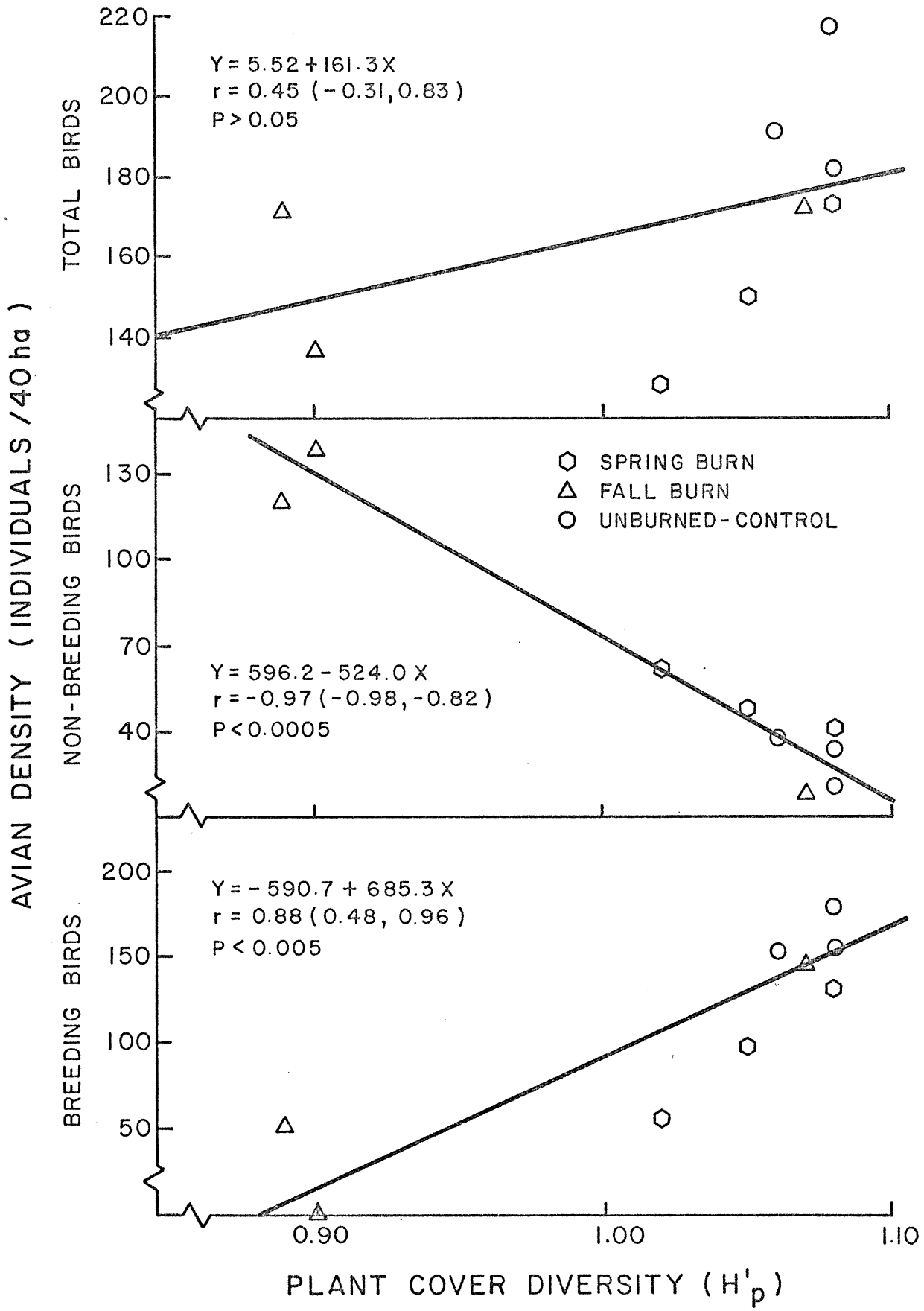

AVIAN DENSITY (INDIVIDUALS/40 ha)
TOTAL BIRDS
NON-BREEDING BIRDS
BREEDING BIRDS
Y = 5.52 + 161.3X
r = 0.45 (-0.31, 0.83)
P > 0.05
Y = 596.2 - 524.0 X
r = -0.97 (-0.98, -0.82)
P < 0.0005
Y = -590.7 + 685.3 X
r = 0.88 (0.48, 0.96)
P < 0.005
SPRING BURN
FALL BURN
UNBURNED - CONTROL
220
200
180
160
140
130
100
70
40
200
150
100
50
0.90
1.00
1.10
PLANT COVER DIVERSITY (H'p)

Fig. 5. Total bird species diversity (H') patterns on Burro Hill study areas. Months are divided into 10-day units.

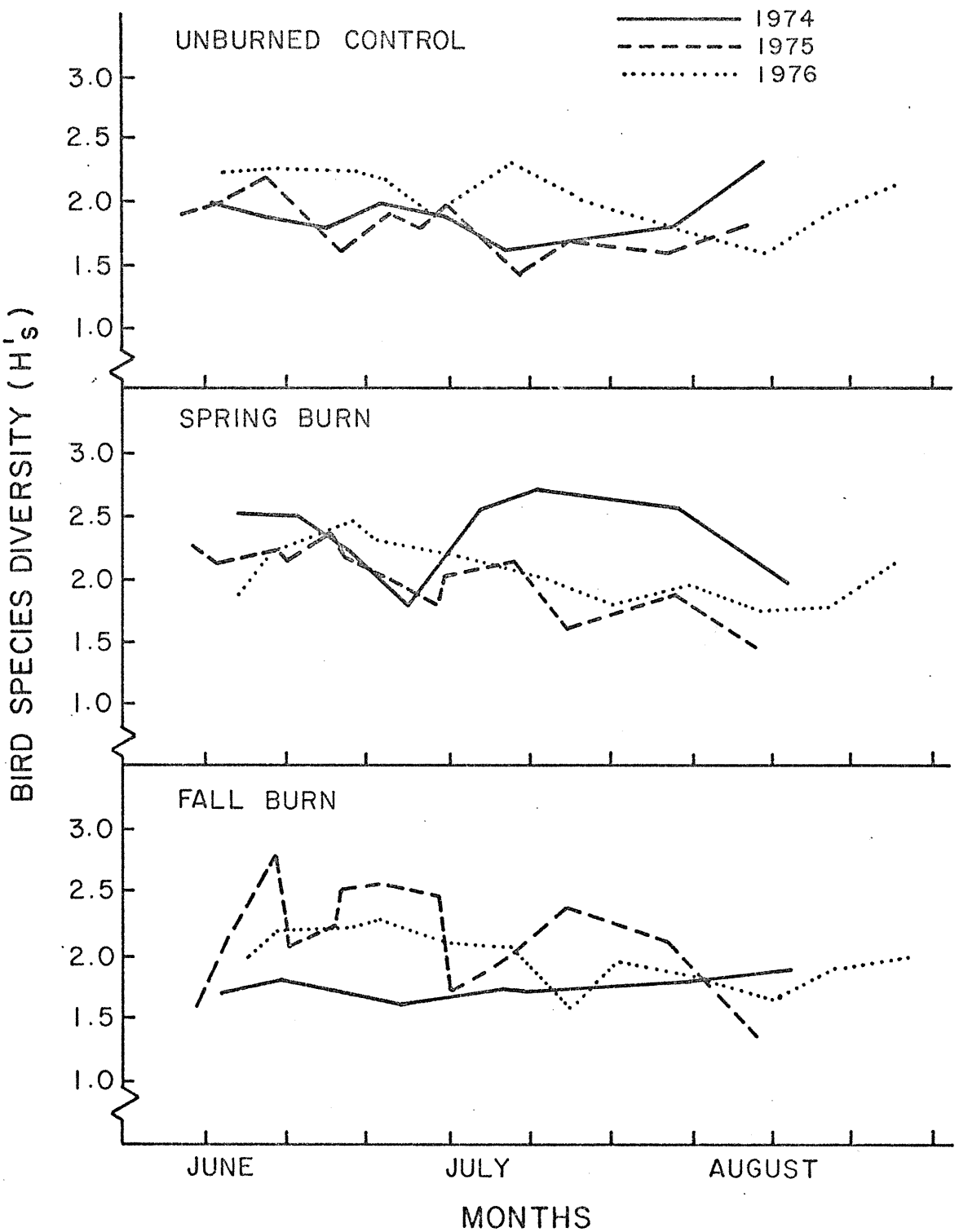

UNBURNED CONTROL
1974
1975
1976
SPRING BURN
FALL BURN
BIRD SPECIES DIVERSITY (H's)
3.0
2.5
2.0
1.5
1.0
JUNE
JULY
AUGUST
MONTHS

Fig. 6. Species richness (S) patterns on Burro Hill study areas. Months are divided into 10-day units.

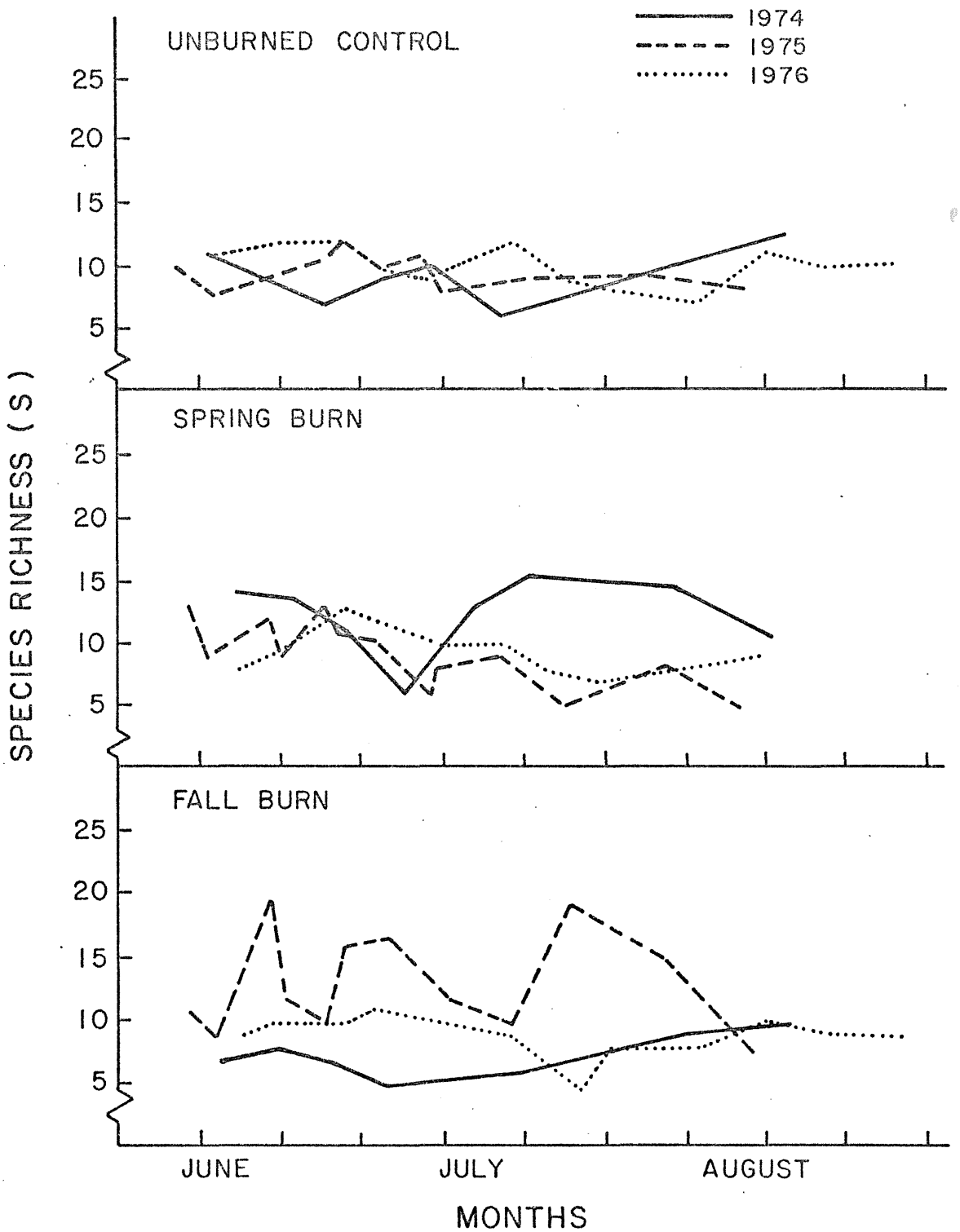
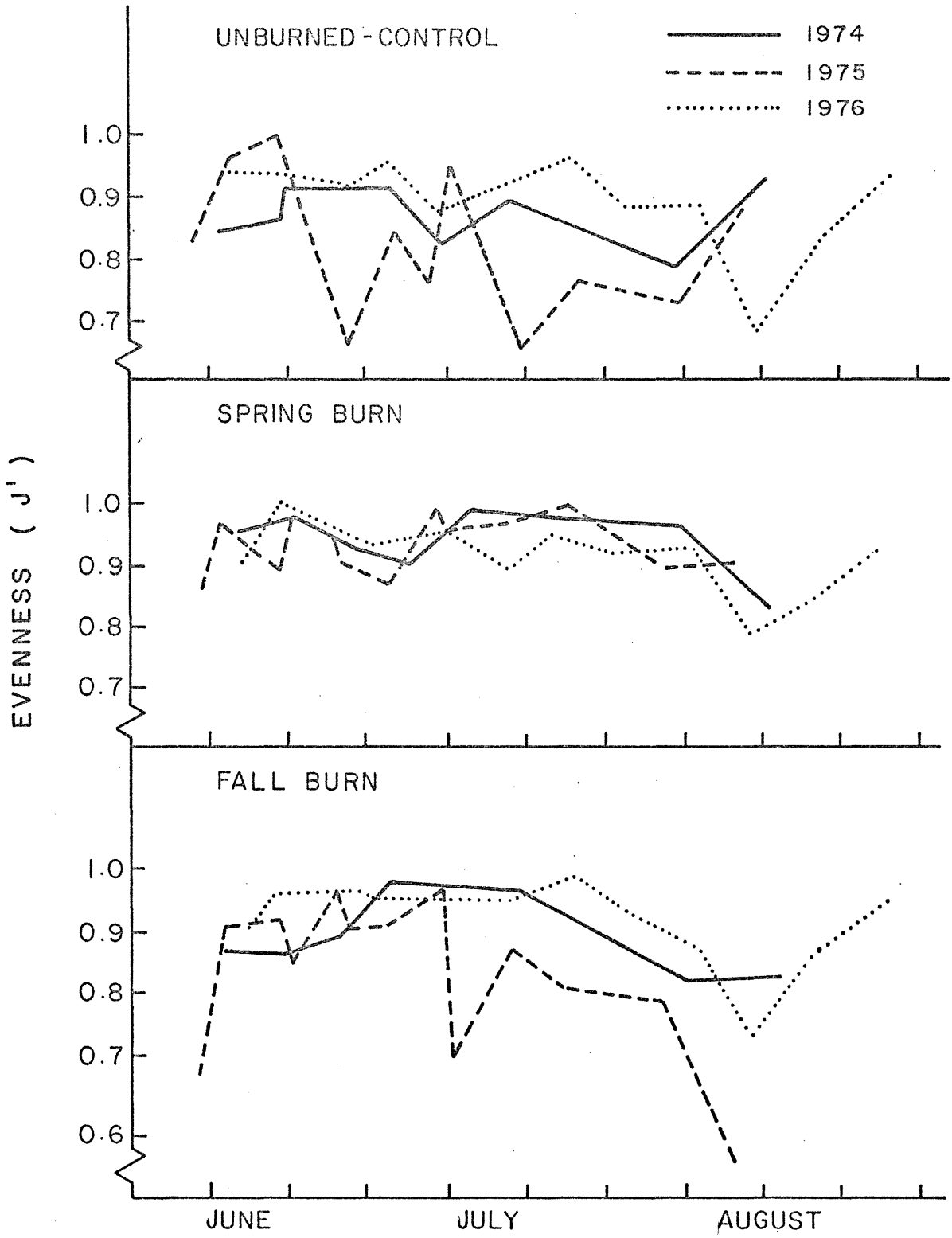

1974
1975
1976
UNBURNED CONTROL
SPRING BURN
FALL BURN
SPECIES RICHNESS (S)
25
20
15
10
5
JUNE
JULY
AUGUST
MONTHS

Fig. 7. Evenness (J') patterns on Burro Hill study areas. Months are divided into 10-day units.


UNBURNED - CONTROL
1974
1975
1976
SPRING BURN
FALL BURN
EVENNESS (J')
1.0
0.9
0.8
0.7
0.6
JUNE
JULY
AUGUST

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SECTION II

SMALL MAMMAL POPULATIONS IN A FIRE-SUPPRESSED AND EARLY FIRE-SUCCESSIONAL SAGEBRUSH ECOSYSTEM

ABSTRACT

Small mammal populations were studied in a fire-suppressed sagebrush ecosystem and on two sagebrush prescribed burns, one spring burn and one fall burn. Species composition, total density and biomass changed little in the unburned sagebrush while individual species capture rates varied considerably. Stomach contents analysis indicated that the small mammal community is generalized (diversified) in its food habits although individual species are somewhat specialized.

Following spring burning the number of small mammal species, total density and biomass were slightly lower than control levels, and returned to unburned levels after three years. Small mammals shifted their food habits slightly in response to an increased availability of food types on the burn.

Species composition was greatly reduced on the fall burn in the first postburn year. Species with specific niche requirements were unable to sustain populations on the fall burn. Two years after burning, four species were captured, although only two (Peromyscus maniculatus and Spermophilus armatus) were caught in live traps. Total small mammal density increased dramatically in the first postburn year and decreased during the second year but was still significantly higher ($P \leq .10$) than the unburned density. These large increases were due to increased numbers of transient individuals from the surrounding habitat. Food use patterns on the fall burn were similar to those on the spring burn where small mammals utilized their preferred food types in relation to its abundance

or availability. These results support the contention that total small mammal numbers are not depleted by fire, but that there is a differential effect on the species present before burning.

INTRODUCTION

For the past 70-80 years fires have been almost completely suppressed in the intermountain region of the United States. The effects of this suppression on the plants and associated wildlife in sagebrush (Artemisia tridentata)-grassland ecosystems remain unknown. Further, the role of small mammal populations in grassland ecosystems remains incompletely defined (French, et al., 1976). An understanding of these plant-animal relationships is requisite to evaluating suppression programs.

Recently, a fire management plan was implemented for the Teton Wilderness allowing natural fires to burn. Plans to use prescribed fire to simulate the ecological effects of a natural fire regime in Jackson Hole are also being developed (Loope and Wood, 1974). Prescribed burning of sagebrush communities for increased livestock forage production is becoming more common in other areas of the region. Management of sagebrush ecosystems with fire for livestock or wildlife requires information on the interrelationships between plants and animals in the postburn stages.

Responses of small mammals to fire in various ecosystems have been reported in rather general terms. Lawrence (1966) indicated species composition was altered but small mammal abundance was not decreased following fire in chaparral. Stout et al. (1971) reported no unusually high densities of small mammals in a burned coniferous forest in northern Idaho. In addition, Taylor (1973) showed the number of small mammal species increased during the first 25 years following fire in lodgepole

pine (Pinus contorta) forests in Yellowstone National Park. There are no existing studies on the effects of fires on small mammal populations in sagebrush communities in the intermountain region.

This study was designed to determine the species composition, density, biomass and food habits of the small mammal community in a fire-suppressed sagebrush ecosystem; and further, to describe the changes in these parameters following a spring and a fall prescribed burn.

MATERIALS AND METHODS

Description of the Study Area

The study area was on Burro Hill about 40 km northwest of Jackson, Teton County, Wyoming, within the boundaries of the Buffalo Ranger District, Bridger-Teton National Forest (Fig. 1). Burro Hill is on National Forest land in sections 24 and 25, T 45N, R 113W, and sections 19 and 30, T 45N, R 112W.

Burro Hill is bounded on the west, south and east by the Buffalo Fork River, and on the north by irrigated hayfields and a small lake. The elevation ranges from 2097 to 2253 m; the topography is rolling and dips gently to the northeast. Burro Hill is composed of Cretaceous sandstone and shale beds which dip to the north. The south and west slopes were created by glaciers and streams cutting through the layered sedimentary beds. These southwest slopes are very steep (60%+) and seldom retain snow. Soils range from sandy and loamy on the eastern and south borders to silty loam on the major portion of Burro Hill. A seasonal stream meanders through the middle of the study area and supports a Salix spp. dominated community. Numerous small ponds remain throughout the spring and early summer but were dry by mid-July.

The climate of the area is characterized by short, cool summers and cold winters. National Oceanic and Atmospheric Administration Climatological Data for the Moran Station, 16 km WNW of Burro Hill, show a thirty year (1944-1974) mean annual temperature of 1.7°C. Approximately three-fourths of the annual precipitation of 53 cm falls in the form of snow. Mean total summer precipitation (June through August) for the

years 1974 through 1976 was 10 cm. Snow depths frequently exceed 1 m and the snow free period is usually May to November.

In unburned areas mountain big sagebrush (Artemisia tridentata vaseyana) is the dominant shrub forming dense, homogeneous stands. The most common grasses are wheatgrasses (Agropyron spp.), Idaho fescue (Festuca idahoensis), bluegrasses (Poa spp.) and needlegrasses (Stipa spp.). Characteristic forbs include yarrow (Achillea millefolium), wildbuckwheat (Eriogonum umbellatum), geranium (Geranium spp.), lupine (Lupinus spp.) and northwest cinquefoil (Potentilla gracilis). Grasses and forbs form a continuous understory with few open areas. This habitat type is placed within the Canadian life zone according to Beetle (1968). The sagebrush is bordered by stands of Douglas fir (Pseudotsuga menziesii) and aspen (Populus tremuloides).

On 3 June 1974, 15-20 ha were burned by the U.S. Forest Service (spring burn) on the eastern end of Burro Hill, resulting in a mosaic of burned patches ranging from completely burned, to partially burned, to unburned. Approximately 70-80 ha were burned on 27 August 1974 (fall burn) and all living and dead vegetation was consumed. Approximately 40-50 ha of sagebrush were left unburned along the eastern and western ends of Burro Hill. An unburned control study area was established on the eastern end of Burro Hill. Validity of the control was based upon similarity of the vegetation and small mammal community to the fall burn area in preburn state. No major differences in vegetative species composition, soil types, past fire history and grazing pressure were found. The small mammal community on the control showed no large differences in species composition and density from the preburn state on

the fall burn.

Vegetation Sampling

The spring burn was sampled during the first (1974), second (1975), and third (1976) postburn growing seasons. The fall burn was sampled in preburn state (1974), and during the first (1975) and second (1976) postburn growing seasons. The unburned control was sampled in all three years. Plant species composition, frequency of occurrence, and dominance (percent cover) of all vascular understory species were determined by the Daubenmire (1959) canopy coverage method. Forty to fifty quadrats (0.1 m^2) were distributed in a stratified random design on all study areas. Shrubs were sampled using the line intercept method (Canfield, 1941) on ten randomly located 40-m transects. Sampling was conducted at two-week intervals beginning in the first week of June, and continuing through August on all areas. Cover was reported as total cover for each species.

Throughout the growing seasons of 1975 and 1976, biomass of the understory was estimated at two-week intervals on 40 to 50 randomly distributed quadrats (0.1 m^2). Vegetation was clipped within 5 cm from ground level, bagged, returned to the laboratory and frozen for later analysis. Plant material was separated by species, dried at 65°C for 20 hours, and weighed to the nearest 0.1 g. Total understory productivity was the sum of individual species productivities, calculated by dividing individual species biomass peaks by the time required to reach that peak (Odum, 1960). Shrubs on the unburned areas were excluded from biomass and productivity estimates due to time and logistical limitations. When

shrubs were part of the understory in the successional stages they were included in the estimates.

Small Mammal Trapping Effort

Small mammals were assessed on five live trapping grids and five snap trapping removal transects. In 1974, Sherman live-traps were arranged in a 5 x 10 grid with a 10-m spacing on the spring and fall burns, and on the unburned control study area. To obtain more detailed information on the larger Uinta ground squirrels (Spermophilus armatus) [mammalian nomenclature follows Long (1965)], No. 2 Tomahawk, Havahart and National live traps were arranged in a 6 x 7 grid with 20-m spacing on the fall burn study area and one grid on the unburned control in 1975. The size of the area sampled by each grid was estimated including a boundary strip whose width was one-half the distance between trapping stations. Therefore, a Sherman trap grid sampled 0.5 ha while the larger trap grid sampled 1.7 ha.

Animals were live trapped five consecutive nights each month during June, July and August and traps were checked two or three times daily. Traps were baited with peanut butter, rolled oats and bacon grease and replenished when needed. Each Sherman trap contained enough cotton batting to be used as a nest during overnight confinement. All traps were located within 2 meters of the grid intersection with the traps usually placed in the shadow of shrubs to reduce mortality due to heat stress. After burning and during early stages of succession, plant cover was nonexistent in certain areas; therefore, traps were checked more frequently during periods of temperature stress. Each individual was

sexed, weighed, examined for reproductive status and marked by toe clipping. Ground squirrels were tagged with Series No. 1 fingerling tags (National Band and Tag Co.). All animals were released at their site of capture.

Removal transects were established in 1975 to collect data on food habits and reproduction. Two parallel transect lines were established on the fall burn and control area, and one line in the spring burn area. Transects were located so as not to influence live-trapping grids. Two Museum Special snap traps and one Victor rat trap were placed at each of twenty stations with a 20-m spacing between stations. Traps were checked twice daily for three consecutive nights each month. Captured animals were returned to the laboratory and frozen for later analysis.

Population and Biomass Estimates

The total number of small mammals in the live-trapping areas was estimated by modification of the Lincoln Index (Bailey, 1952):

$$\hat{N}_T = \frac{m(c + 1)}{(r + 1)} .$$

$\hat{N}_T$ is the estimated total number of individuals; m is the number of different individuals captured in the first four nights of the trapping period; c is the number captured on the fifth night; and r is the number of different individuals captured on the fifth night that had been captured at least once during the previous four nights. This estimate of total number in the trapping area does not include young that had not been weaned, since these individuals rarely leave their home burrows and consequently are not trapable. Where total captures were not sufficient

to use this method, the number of different individuals captured during the session was used as a minimum number present. In cases where an individual was not captured in a given session, but was trapped in preceding and succeeding sessions, I considered the animal to have been present in the area during the intermediate session. Biomass of small mammals was calculated using live body weights obtained from captured individuals.

Food Habits

Food habits of small mammals were studied on the spring burn in its second (1975) and third (1976) postburn years and on the fall burn in its first (1975) and second (1976) postburn years. The unburned control was also sampled in 1975 and 1976. Information was obtained from 305 snap-trapped individuals. Stomachs were removed after capture and preserved in 10% formalin until examination. Stomach contents were removed and separated under a dissecting microscope into five groups: seed, green vegetation, animal material, bait, and unidentified material. The wet weight of each group was recorded to the nearest 0.001 g. The proportion and percent occurrence of each group in the diet of each captured species were calculated.

RESULTS

Eight species of rodents, two species of insectivores and one carnivore were captured during the three-year period: the deer mouse (Peromyscus maniculatus), Uinta ground squirrel (Spermophilus armatus), western jumping mouse (Zapus princeps), montane vole (Microtus montanus), least chipmunk (Eutamias minimus), long-tailed vole (Microtus longicaudus), northern pocket gopher (Thomomys talpoides), red-backed vole (Clethrionomys gapperi), vagrant shrew (Sorex vagrans), cinereus shrew (Sorex cinereus), and long-tailed weasel (Mustela frenata) (Table 1). No species was recaptured in sufficient numbers on all areas in all years to warrent comparison by the Lincoln Index. Therefore, total captures and trapping frequencies (catch per unit effort) for individual species are presented. The Lincoln Index was used to estimate total small mammal population density when applicable. Overlap of the 95 percent confidence interval indicates no significant difference in total density at approximately the 0.10 level (McDonald, 1976, personal communication). Succeeding statements on significance between total density estimates refer to this overlap and probability level.

Species Composition, Population Density and Biomass

Unburned control. -- Species composition changed little while capture rates of different species varied considerably during the study period (Tables 1 and 2). Peromyscus captures fluctuated most between years showing a steady increase over the three years. Spermophilus capture

rates also increased but this was due to the more efficient trapping procedures on the large grid in 1975 and 1976. However, the numbers of different Spermophilus individuals caught in 1975 and 1976 did not differ greatly from 1974. Sorex also showed a general increase in capture rates, while Zapus, Eutamias and Mustela capture rates were relatively steady. No Microtus montanus were captured in 1975 and the cause is unknown. Populations of this microtine are cyclic and could possibly have been in a decline at that time. Thomomys numbers are most likely underestimated since this animal is primarily a burrower and no effort was made to trap this species underground. Clethrionomys is usually considered a forest dweller and the single individual captured may have been exploring from the surrounding forest. However, this individual was a mutant carrying macrocytic anemia (Pinter, 1975, personal communication). No other specimens were captured on any area in all years.

Sex ratios were essentially 1:1 for all species and very few transients of any species were detected on the unburned sagebrush plot in all summers. Almost all individuals recaptured were resident members who remained on the plot during the summer. Transients were those individuals which were captured in one trapping session but were never recaptured while residents were recaptured.

The small mammal community in the control sagebrush ecosystem showed little change in total density and biomass over the three summers (Figs. 2 and 3). Total numbers did not differ significantly among summer months in all years. Biomass peaked in July or August, and except for June 1975, the general pattern was identical to total density.

Spring Burn. -- The number of species occurring on the spring burn in the first and second postburn years was slightly lower than on the control. Three years after spring burning species richness had returned to control levels (Table 1).

In the first postburn season (1974) total density was lower than the control in all summer months (Fig. 2) due to low numbers of Zapus, Spermophilus and Microtus (Table 2). Total density increased in the second year postburn due to an increase in the numbers of Peromyscus (Table 2). More than one-half the Peromyscus captured on the live trap plot in 1975 were transients. These individuals were rarely recaptured in succeeding trapping sessions and most likely moved out of the area. However, a similar increase in total density occurred on the unburned control also due to Peromyscus. These differences in total density between the burn and control in 1975 were not significant.

In the third year postburn total density on the spring burn in all summer months did not differ significantly from unburned values but was higher than estimates in the first year postburn (1974). Zapus numbers were still low after three years; however, Spermophilus and Microtus populations were slightly higher (Table 2). Peromyscus density was also markedly lower on the burn in the third postburn years. No Sorex were captured in the first two years postburn but capture rates increased in 1976. Eutamias, Thomomys and Mustela numbers remained relatively unchanged. Sex ratios of the most frequently captured species were essentially 1:1. Biomass followed the same patterns as density except in July 1975 (Fig. 3) when Spermophilus captures were highest.

Fall Burn. -- Small mammal species composition changed dramatically on the fall burn (Table 1). Six species present in the preburn state were absent in the first year postburn. The presence of Zapus on the burn in the first postburn year was doubtful as the seven individuals captured on the burn were taken at a snap trap station nearest (~200 m) unburned aspen. These individuals may represent exploring or dispersing members from the unburned areas. In the second year postburn Zapus and Microtus re-established populations on the burn as individuals were captured at trap stations well within the burn. Microtus longicaudus and Sorex cinereus may be rare to the sagebrush ecosystem on Burro Hill as only two specimens of M. longicaudus and one S. cinereus individual were taken in the three years of study. Negus and Findley (1959) show these species to be more common in hydrosere communities.

In the first year postburn (1975) only Peromyscus and Spermophilus were captured on the live trap grid, and their numbers and capture rates increased greatly. Increases were also detected on the control but not nearly of the magnitude observed on the burn grid. Snap trap results on the fall burn also indicated an increase in Peromyscus, whereas the capture rate of Spermophilus decreased. This decrease may be an artifact of the snap trap sampling method since the trap stations contained only one rat-sized trap, and many Peromyscus were captured in them, thereby decreasing the number of traps available to capture a Spermophilus. No Spermophilus were taken in the smaller traps. The high density of Peromyscus was due to increased transient individuals. Preburn populations consisted primarily of residents, whereas in both postburn years transients were captured more often. However, the number

of resident animals also increased on the plot after burning. The Spermophilus population consisted primarily of residents. Sex ratios of the resident Peromyscus and Spermophilus populations were essentially 1:1, while transients were predominantly males.

Total small mammal density estimates also increased sharply in 1975. Total density increased in a linear fashion during the summer, where control values decreased slightly. The large increase in total density on the fall burn was due entirely to the increases in Peromyscus and Spermophilus numbers.

In the second year postburn (1976) total density was still significantly higher than unburned control values in June and August. Capture rates for Peromyscus were higher than in 1975 although the number of different individuals caught decreased. Spermophilus capture rates decreased slightly from 1975 as did the number of individuals. The summer density pattern on the burn in 1976 also changed, with a slight decrease in July although the peak density still occurred in August. This pattern is the same as observed on the control in 1974. Total biomass patterns on the fall burn in all summers were identical to total density patterns (Fig. 3). The large increases in biomass in 1975 and 1976 were due to increased Peromyscus and Spermophilus numbers.

After the first postburn year following fall burning, total vegetation cover was still sparse (Table 3); however, during the second postburn year total cover increased from 24 percent to 68 percent. Total small mammal density increased greatly following burning and decreased with revegetation, but total density and biomass, and numbers of Peromyscus and Spermophilus, were still higher than unburned

estimates. These increases may have been a response to reduced competition or the increased availability of food (see Food Habits section), which attracted large numbers of animals from the surrounding habitat.

Food Habits

The mean percent weight, frequency of occurrence and proportion of the diet of the five food groups for each species are shown in Table 4 and Fig. 4. These results represent summer diets and should not be construed to represent the entire diet of the species.

Unburned control. -- In the unburned sagebrush the small mammals appear to have well segregated food niches. Each primary food type (seed, green vegetation or animal material) was utilized essentially by one or two species. Spermophilus and Microtus are primarily herbivores, while Zapus consumed seeds with some green vegetation. Peromyscus concentrated on animal (mainly insect) material, although not exclusively. Spermophilus in this region are generalized and opportunistic in their diet (Costain, 1975, personal communication) while Maxell (1973) found that Richardson's ground squirrel (S. richardsonii) in the Great Divide Basin of Wyoming feeds primarily on foliage. Pinter (1975, personal communication) has confirmed Microtus montanus in Jackson Hole to be mainly herbivorous. Clark (1971) has shown Zapus in Jackson Hole to be granivorous with incidental use of green vegetation, and Clark (1975) has also indicated Peromyscus to be omnivorous, with arthropods comprising 48 percent of the summer diet. Therefore, the small mammal

community in the fire-suppressed sagebrush ecosystem consisted of one large and one small herbivore, one small granivore, and one small omnivore. Other species present were snap trapped in fewer numbers and no stomachs were examined. These included one insectivore (Sorex), one granivore (Eutamias), one herbivore (Thomomys) and one carnivore (Mustela).

The small mammal community in unburned sagebrush appears to be linked to the resource base through its food habits. The relative amount of seed, green vegetation and animal material utilized by the populations show variation in resource use among species. Their nearly equal utilization of the primary food types indicates that the total small mammal community is generalized (diversified) in its food habits, although individual species are somewhat specialized (Table 4).

Spring Burn. -- In 1975 total productivity of the understory on the burn increased almost two-fold above unburned estimates providing an increased amount of green vegetation (Table 5). Fires in chaparral communities are known to concentrate seeds of grasses and shrubs on the soil surface (Lawrence, 1966; Sweeney, 1956). Insect numbers on the soil surface are also known to be high following chaparral fires (Lawrence, 1966). Following this increased availability of food a slight shift in small mammal diets was detected on the spring burn in 1975. Spermophilus stomachs contained a higher proportion (90%) of green vegetation than specimens from the unburned sagebrush. Although the proportion of seed and animal material changed little, occurrence in the diet increased. Zapus continued to concentrate on seeds and

green vegetation, while Peromyscus took more seeds and green vegetation in both postburn years.

In 1976 the burned areas were completely revegetated and Peromyscus numbers and seed utilization declined. Spermophilus numbers and green vegetation use also followed this pattern. Zapus stomachs contained more seed material in 1975 when seeds were more readily available, and less in 1976. The insectivore Sorex was absent on the burn in 1974 and 1975 but was captured at similar rates in 1976 as the unburned control. This decrease in Sorex numbers was most likely in response to some factor other than food, since insect numbers were presumably higher on the burned areas.

Fall Burn. -- In the first year following fall burning the amount and availability of green vegetation was greatly reduced, but increased markedly in the second postburn year (Tables 3 and 5). It is assumed that seed availability was increased in both postburn years. Significant changes in small mammal food habits followed these changes in food availability. In the first postburn season Peromyscus stomachs contained equal amounts of seed and animal materials but the proportion and frequency of seed material was higher than observed in specimens from the control and spring burn (Table 4). Spermophilus responded by taking less green vegetation in 1975 and considerably more in 1976. The utilization of seeds and green vegetation by Zapus remained largely unchanged. Microtus was captured only in 1976 and this species' food habits were essentially similar to unburned control specimens.

Reproduction

The breeding season of Spermophilus on the Burro Hill study areas probably occurred in early to late spring (April-May), with young being born in late May through early June. Since trapping did not begin prior to the first of June, no pregnant females of this monestrus rodent were collected. No conclusions can be made on the reproductive status of Spermophilus on the study areas.

Embryo and placental scar counts were made for parous female rodents collected in snap traps in 1975 and 1976 (Table 6). Peromyscus is polyestrus and was reproductively active throughout the summer on Burro Hill. Long (1964) reported a mean litter size of 6.0 (range 5-7) for five female Peromyscus from northwestern Wyoming. The data from my study agree closely with Long's estimates except on the fall burn in 1975 (first postburn year). The placental scar count was considerable higher than the embryo count suggesting possible resorption of embryos. These data, and the occurrence of embryo counts of 11 and placental scar counts of 10 which is probably near the upper limit for this rodent, suggest a maximization of reproductive potential in response to certain environmental factors such as food and space availability.

Results obtained on Zapus closely agree with those of Clark (1971). No remarkable differences in Zapus reproduction occurred on any study area in 1975 or 1976. The limited data on Microtus show mean embryo and placental scar counts slightly higher than observed by Clark (1973).

DISCUSSION

Information obtained on species composition and density in the fire-suppressed sagebrush indicates that the small mammal community consists of a mixture of species whose total numbers vary little. Small mammals in the unburned sagebrush were captured at low rates in 1974, while species capture rates and total density estimates increased slightly in 1975 and 1976. These changes in density were most likely a function of natural population fluctuations. There was little dietary overlap among the species. The different species were partitioned along the food dimension with Spermophilus (herbivore), Microtus (herbivore), Zapus (granivore) and Peromyscus (omnivore) each specializing in one food type.

Total small mammal densities were at low levels following spring burning, but this was short-lived. By the end of the second postburn year densities were similar to unburned control estimates with the responses being caused by one or two species. The unburned and partially burned islands that remained following the burn undoubtedly served as refuges for small mammals. Three years after spring burning total cover of the understory was near unburned levels, and small mammal numbers were not significantly different from control values.

The fall burn differed from the spring burn in that no patches of unburned sagebrush remained and revegetation was slower. One year after burning, total cover was still dramatically lower than unburned estimates although Peromyscus and Spermophilus numbers had increased dramatically.

It appears that the loss of cover had no negative effects on their densities, and that food was the factor affecting them most. Both Peromyscus and Spermophilus changed their food habits to utilize the increased availability of preferred food types. The absence of potentially competitive species may also have enhanced their success, since species with rather specific niche requirements (e.g., Microtus, Zapus and Sorex) cannot sustain populations on severe fall burns. Cook (1959) discovered that lack of cover following burning is the restricting factor in reducing Microtus populations which require one year of mulch for runways. Zapus nest on the surface under protection of grasses and herbs (Burt and Grossenheider, 1964), and Whittaker (1963) suggested that the absence of a well-developed, extensive herbaceous layer may exclude Zapus. Stout et al. (1971) correlated the absence of shrews (Sorex spp.) on a burned coniferous forest in northern Idaho with their limited powers of dispersal and the lack of ground litter on the burned sites. Stout's data also indicated a significantly reduced number of species of small mammals in the years following the burn.

Peromyscus maniculatus is particularly suited to exploit burns since it prefers seeds of grasses and herbs and insects (Drickamer, 1970). Spencer (1955) and Ahlgren (1966) contend that accumulations of seeds remain in unburned portions of forest floors and production by annual grasses is sufficient to support substantial populations of seed-eating rodents. Many authors (Tevis, 1956; Cook, 1959; Gashwiler, 1959; Lawrence, 1966) have shown that granivores are favored in the initial stages of secondary succession following fire. Cook (1959) reported an irruption of western harvest mice (Reithrodontomys megalotis)

during a period of maximum seed production. Both Cook (1959) and Lawrence (1966) have documented the shift in Peromyscus species abundance to favor P. maniculatus in the years following burn. Ahlgren (1966), Beck and Vogl (1972) and Tevis (1956) found significantly higher populations of P. maniculatus in burned areas. In addition, Ahlgren (1966), Spencer (1955) and Tester (1965) contend that burning improved habitat and food conditions for small rodents. Kirkland (1976) describes a case of opportunism by P. maniculatus on mine wastes in New York and attributes its success to its ecological plasticity and the absence of congeneric competitors. The results from my study further illustrate the broad ecological tolerance of P. maniculatus and reflect the adaptability of this species in invading and exploiting harsh habitats. I attribute its success on the burns to increased immigration from surrounding areas and a maximization of reproductive potential in response to an increased availability of food.

In conclusion, the suppression of fire in mountain big sagebrush communities has resulted in a small mammal fauna having strong associations with vegetation structure and food types. Spring and fall prescribed burning altered species composition and produced quantitatively different responses by individual species. These changes associated with burning are considered to be directly related to the alteration of the vegetation in that the burns not only changed the structure of the community but altered food habits, and reproductive patterns. These results support the contention that total small mammal numbers are not depleted by fire, but that there is a differential effect on the species present before burning.

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Table 1. Small mammal species on Burro Hill study areas, where X indicates presence on trapping grids.

	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-burn	Postburn	
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Peromyscus maniculatus	X	X	X	X	X	X	X	X	X
Spermophilus armatus	X	X	X	X	X	X	X	X	X
Zapus princeps	X	X	X	X	X	X	X	X	X
Microtus montanus	X		X			X	X		X
Sorex vagrans	X	X	X		X	X	X		
Eutamias minimus	X	X	X	X	X	X	X		
Mustela frenata	X	X	X	X	X	X	X		
Thomomys talpoides	X	X	X	X	X	X			
Clethrionomys gapperi		X							
Microtus longicaudus							X		
Sorex cinereus							X		
Total Number Species	8	8	8	6	7	8	9	3	4

Table 2. Species composition, total captures, and catch per unit effort (in parentheses expressed as the number captured per 100 trap nights) of small mammals for the Burro Hill study areas in 1974-1976.

Species	Sherman Live Trap			Ground Squirrel Live Trap		Snap Trap		Totals		
	1974	1975	1976	1975	1976	1975	1976	1974	1975	1976
Unburned Control:										
Peromyscus maniculatus	6 (0.4)	36 (2.4)	60 (4.0)	0	0	3 (0.2)	26 (2.4)	6 (0.4)	39 (1.9)	86 (4.2)
Spermophilus armatus	8 (0.5)	0	0	16 (2.5)	20 (3.2)	6 (0.6)	10 (0.9)	8 (0.5)	22 (1.1)	30 (1.5)
Zapus princeps	17 (1.1)	24 (1.6)	23 (1.5)	0	0	5 (0.5)	8 (0.7)	17 (1.1)	29 (1.4)	31 (1.5)
Microtus montanus	11 (0.7)	0	6 (0.6)	0	0	0	4 (0.3)	11 (0.7)	0	10 (0.5)
Sorex vagrans	2	8 (0.5)	16 (1.1)	0	0	0	0	2	8 (0.5)	16 (1.1)
Eutamias minimus	2	2	2	0	0	0	0	2	2	2
Mustela frenata	1	2	1	0	0	0	0	1	2	1
Thomomys talpoides	0	0	3	0	0	0	0	0	0	3
Clethrionomys gapperi	0	1	0	0	0	0	0	0	1	0

Table 2. (Continued)

Species	Sherman Live Trap			Ground Squirrel Live Trap		Snap Trap		Totals		
	1974	1975	1976	1975	1976	1975	1976	1974	1975	1976
Spring Burn:										
Peromyscus maniculatus	9 (0.6)	58 (3.9)	24 (1.6)	--	--	20 (3.7)	22 (4.0)	9 (0.6)	78 (3.8)	46 (2.3)
Spermophilus armatus	12 (0.8)	7 (0.5)	29 (1.9)	--	--	2 (0.4)	9 (1.7)	12 (0.8)	9 (0.4)	38 (1.9)
Zapus princeps	1	4 (0.3)	9 (0.6)	--	--	12 (2.2)	13 (2.4)	1	16 (0.8)	22 (1.1)
Microtus montanus	0	0	20 (1.3)	--	--	0	0	0	0	20 (1.3)
Sorex vagrans	0	1	10 (0.7)	--	--	0	0	0	1	10 (0.7)
Eutamias minimus	4 (0.3)	2	3	--	--	0	0	4 (0.3)	2	3
Mustela frenata	1	2	0	--	--	0	0	1	2	0
Thomomys talpoides	0	1	1	--	--	0	0	0	1	1

Table 2. (Continued)

Species	Sherman Live Trap			Ground Squirrel Live Trap		Snap Trap		Totals		
	1974	1975	1976	1975	1976	1975	1976	1974	1975	1976
Fall Burn:										
Peromyscus maniculatus	4 (0.3)	284 (18.9)	305 (20.3)	0	0	113 (10.5)	157 (14.5)	4 (0.3)	397 (19.5)	462 (22.7)
Spermophilus armatus	60 (4.0)	0	0	155 (24.6)	145 (23.0)	5 (0.5)	17 (1.6)	60 (4.0)	160 (7.8)	162 (7.9)
Zapus princeps	4 (0.3)	0	0	0	0	7 (0.7)	4 (0.3)	4 (0.3)	7 (0.3)	4 (0.2)
Microtus montanus	5 (0.4)	0	0	0	0	0	7 (0.7)	5 (0.3)	0	7 (0.3)
Eutamias minimus	4 (0.3)	0	0	0	0	0	0	4 (0.3)	0	0
Sorex vagrans	2	0	0	0	0	0	0	2	0	0
Microtus longicaudus	2	0	0	0	0	0	0	2	0	0
Mustela frenata	1	0	0	0	0	0	0	1	0	0
Sorex cinereus	1	0	0	0	0	0	0	1	0	0

Table 3. Dominance (percent cover) of major plant groups on Burro Hill study areas. Values are means for six sampling dates during the growing season. See Appendix III for individual species contributions.

Plant Group	Unburned Control			Spring Burn			Fall Burn		
				Postburn			Pre-burn	Postburn	
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Shrubs	50	49	48	10	15	19	48	3	9
Grass and grass-like plants	27	30	28	14	19	22	33	6	15
Forbs	30	35	41	26	32	31	40	15	44
Total Cover	107	114	117	50	66	72	121	24	68

Table 4. Proportion and occurrence of food groups in the diets of small mammals from the Burro Hill study areas in 1975 and 1976. The mean percent weight is followed by the percent occurrence in parentheses.

	% Total Weight (% occurrence)									
	Seed		Green Vegetation		Animal		Bait		Unidentified	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
UNBURNED CONTROL										
Peromyscus maniculatus	8(33)	5(19)	3(33)	6(14)	58(80)	54(86)	8(15)	10(24)	23(100)	25(100)
Spermophilus armatus	2(33)	0	73(100)	85(100)	2(33)	0	20(100)	10(83)	3(33)	5(67)
Zapus princeps	69(100)	80(100)	30(20)	18(29)	1(20)	1(14)	0	1(20)	0	0
Microtus montanus	---	20(100)	---	65(100)	---	5(75)	---	10(100)	---	0
SPRING BURN										
Peromyscus maniculatus	23(80)	18(42)	9(50)	17(75)	35(100)	40(92)	18(70)	15(50)	15(100)	10(100)
Spermophilus armatus	2(100)	2(17)	90(100)	91(100)	0	1(17)	4(100)	5(33)	4(100)	1(17)
Zapus princeps	76(100)	70(100)	22(71)	28(50)	0	1(13)	2(13)	1(50)	0	0
FALL BURN										
Peromyscus maniculatus	35(100)	30(100)	5(25)	20(15)	35(100)	30(93)	20(50)	10(76)	5(48)	10(62)
Spermophilus armatus	20(60)	5(30)	50(100)	90(100)	10(40)	0	20(100)	4(80)	0	1(30)
Zapus princeps	70(100)	85(100)	30(100)	10(67)	0	0	0	1(33)	0	4(100)
Microtus montanus	---	10(43)	---	85(100)	---	0	---	3(71)	---	2(100)

Table 5. Primary productivity estimates (grams·m^{-2}·day^{-1}) of the understory on Burro Hill study areas in 1975 and 1976.

Plant Group	Unburned Control		Spring Burn		Fall Burn	
	1975	1976	1975	1976	1975	1976
Shrubs	0.0309	0.3200	0.6977	0.9021	0.2096	0.4821
Grass and grass-like plants	2.4525	2.7235	7.8708	3.5614	0.8293	5.8124
Forbs	2.2139	2.8369	5.2069	5.0944	2.9388	10.8284
Total	4.6973	5.8804	8.7754	9.5579	3.9777	17.1229

Table 6. Reproductive status of female small mammals taken in snap-traps on Burro Hill study areas in 1975 and 1976, * = no specimens examined, - = no range.

Species	Spring Burn 1975 mean	Spring Burn 1975 range	Spring Burn 1976 mean	Spring Burn 1976 range	Fall Burn 1975 mean	Fall Burn 1975 range	Fall Burn 1976 mean	Fall Burn 1976 range	Unburned Control 1975 mean	Unburned Control 1975 range	Unburned Control 1976 mean	Unburned Control 1976 range
					E M B R Y O S							
Peromyscus maniculatus	6.0	4-8	6.1	4-9	6.1	4-11	5.8	4-8	6.0	--	5.8	4-8
Zapus princeps	4.5	0-9	5.0	4-6	5.0	4-6	5.0	3-7	5.1	4-7	5.0	4-6
Microtus montanus	*	*	*	*	*	*	7.0	--	*	*	7.2	4-9
					P L A C E N T A L S C A R S							
Peromyscus maniculatus	5.7	5-7	5.7	5-7	7.8	5-10	6.0	4-9	6.0	--	6.0	4-8
Zapus princeps	4.4	3-6	4.5	3-7	0	--	0	--	4.9	4-6	4.6	4-7
Microtus montanus	*	*	*	*	*	*	0	--	*	*	7.0	--

Fig. 1. Burro Hill study area on Bridger-Teton National Forest.

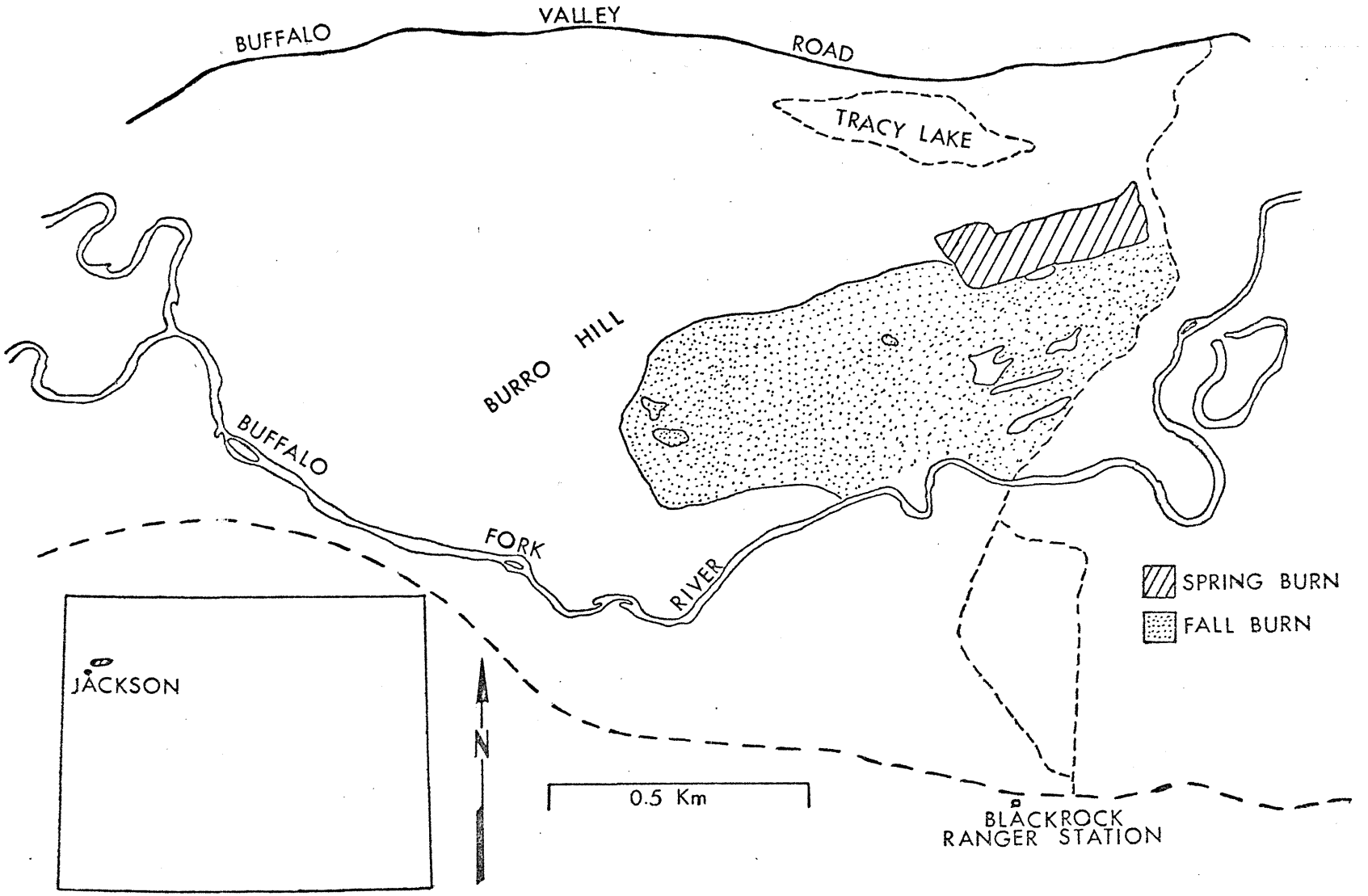

BUFFALO VALLEY ROAD
TRACY LAKE
BURRO HILL
BUFFALO FORK RIVER
SPRING BURN
FALL BURN
JACKSON
N
0.5 Km
BLACKROCK RANGER STATION

Fig. 2. Total small mammal density estimates for the Burro Hill study areas, 1974-1976. Values are based on the minimum number present (o), and modified Lincoln Index estimates (bars). Vertical lines are the 95% confidence limits for Lincoln Index estimates. C = unburned control, S = spring burn, F = fall burn.

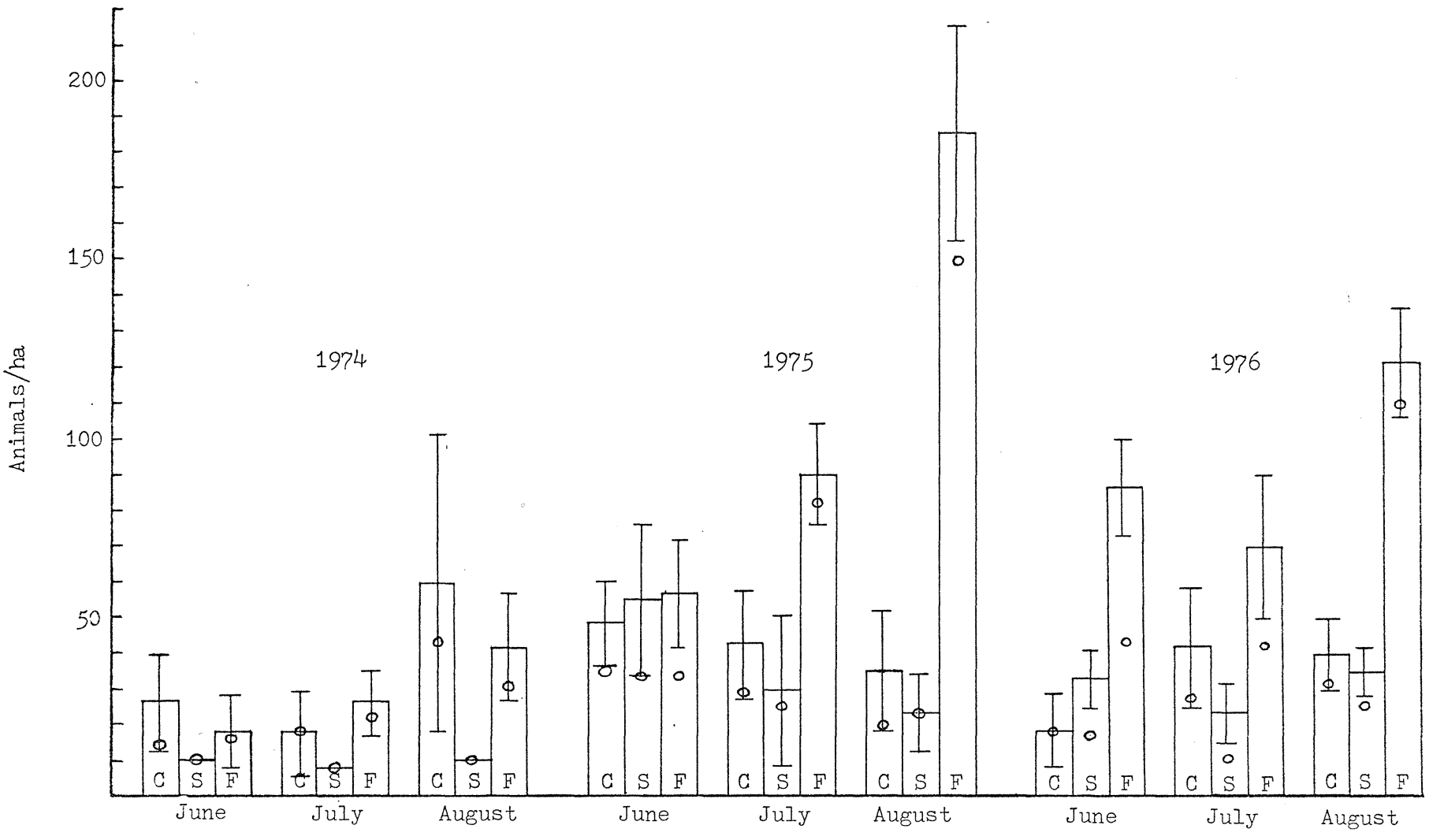

Animals/ha
200
150
100
50
1974
1975
1976
C
S
F
June
July
August

Fig. 3. Total small mammal biomass estimates for the Burro Hill study areas, 1974-1976. C = unburned control, S = spring burn, F = fall burn.

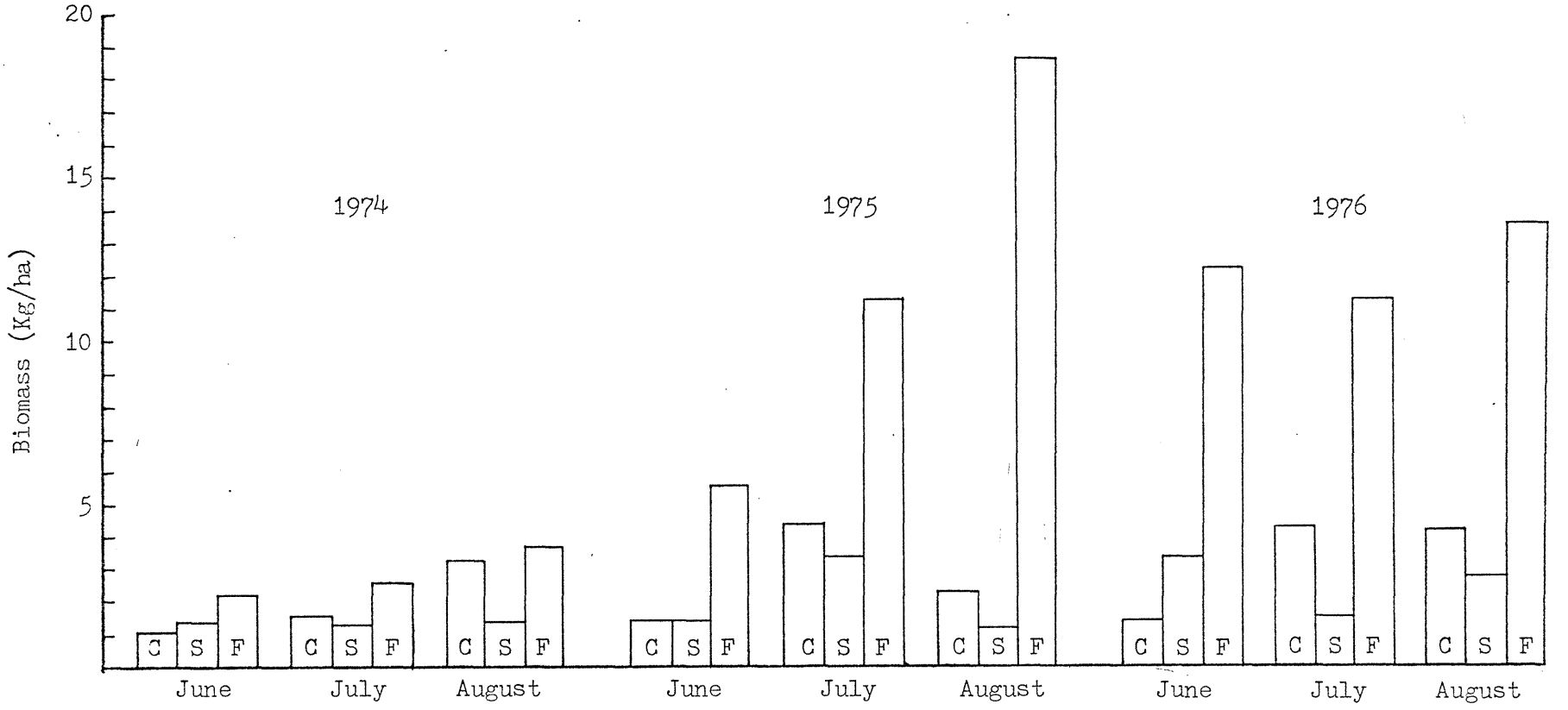
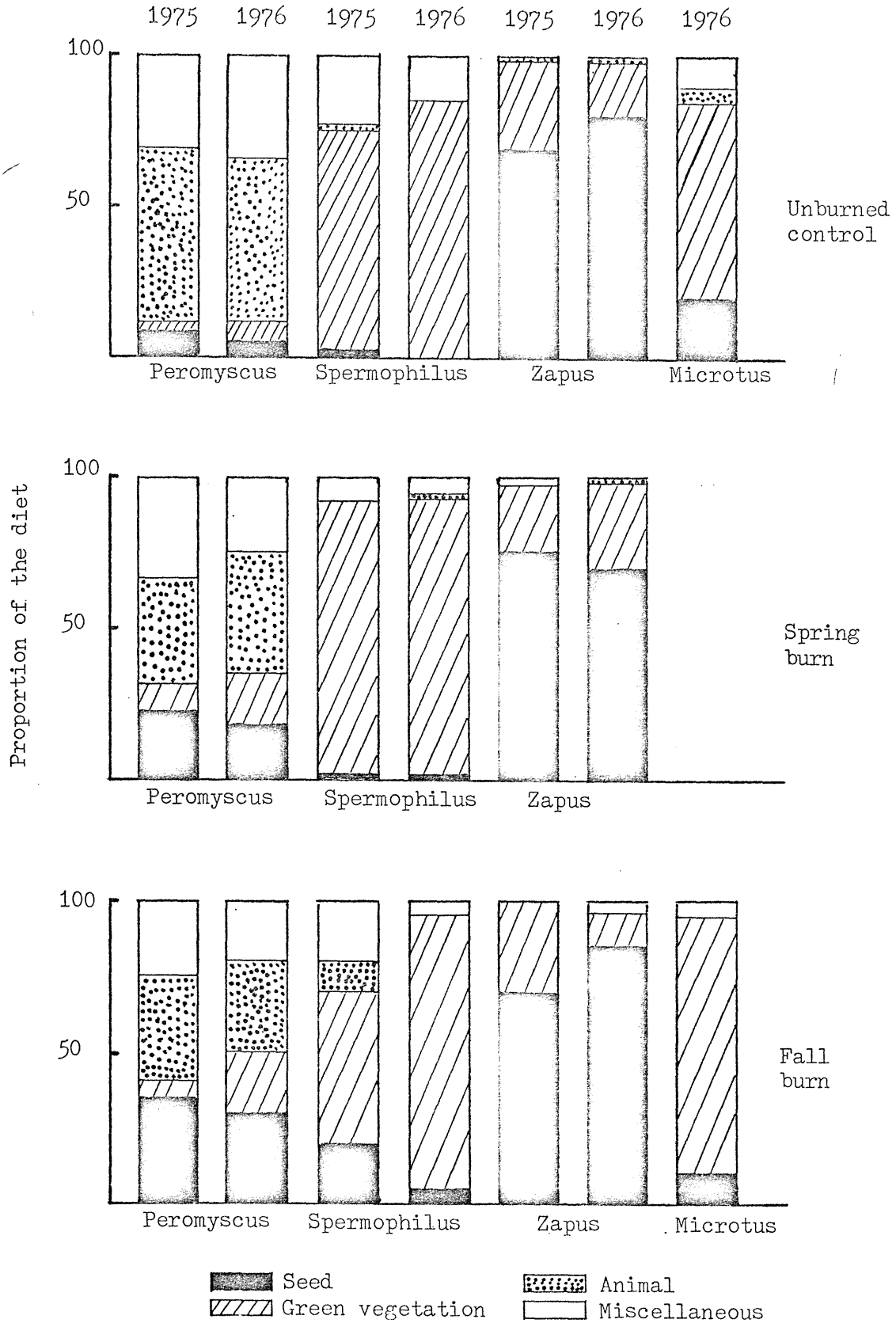

Biomass (Kg/ha)
20
15
10
5
1974
1975
1976
C S F
June
July
August

Fig. 4. Proportion (percent) of the diet of food types for small mammals on Burro Hill study areas.


1975
1976
1975
1976
1975
1976
1976
100
50
Unburned control
Peromyscus
Spermophilus
Zapus
Microtus
Proportion of the diet
100
50
Spring burn
Peromyscus
Spermophilus
Zapus
100
50
Fall burn
Peromyscus
Spermophilus
Zapus
Microtus
Seed
Green vegetation
Animal
Miscellaneous

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SECTION III

APPENDICES

APPENDIX I

Plant species collected on Burro Hill study areas in 1974-1976. Nomenclature follows Shaw (1968, 1976); Hitchcock *et al.* (1961, 1964; 1973, 1959).

Species	Life Form	Longevity
BERBERIDACEAE		
Berberis repens Lindl. [*Mahonia repens* G. Don.].	Shrub	Perennial
BORAGINACEAE		
Crypthantha ambigua (A. Gray) Greene.	Forb	Perennial
Hackelia floribunda (Lehm.) I. M. Johnston.	Forb	Biennial or Perennial
Lappula redowskii (Hornem.) Greene.	Forb	Annual
Lithospermum ruderale Dougl.	Forb	Perennial
CAMPANULACEAE		
Campanula rotundifolia L.	Forb	Perennial
CAPRIFOLIACEAE		
Symphoricarpus oreophilus A. Gray var. Utahensis (Rydb.) A. Nels. [*S. vaccinioides* Rydb., *S. tetonensis* A. Nels., *S. rotundifolius*, A. Gray].	Shrub	Perennial
CARYOPHYLLACEAE		
Arenaria congesta Nutt.	Forb	Perennial
Stellaria longipes Goldie var. Altocaulis (Hulten).	Forb	Perennial
CHENOPODIACEAE		
**Chenopodium atrovirens* Rydb.	Forb	Annual
Chenopodium overi Aellen.	Forb	Annual

APPENDIX I (Continued).

Species	Life Form	Longevity
COMPOSITAE		
Achillea millefolium L. spp. lanulosa (Nutt.) Piper.	Forb	Perennial
Agoseris glauca (Pursh.) Raf. Var. Laciniata (D. C. Eaton) Smiley.	Forb	Perennial
Antennaria parvifolia Nutt.	Forb	Perennial
Antennaria rosea (Eat.) Greene.	Forb	Perennial
Arnica sororia Greene.	Forb	Perennial
Artemisia cana Pursh.: ssp. cana var. Viscidual Osterh.	Half-shrub	Perennial
Artemisia tridentata Nutt. ssp. vasyana.	Shrub	Perennial
Aster perelegans Nels. & Macbr.	Forb	Perennial
Balsamorhiza sagittata (Pursh.) Nutt.	Forb	Perennial
Chrysothamnus nauseosus (Pall.) Britt.	Shrub	Perennial
*Cirsium vulgare (Savi) Tenore.	Forb	Perennial
Crepis acuminata Nutt.	Forb	Perennial
Erigeron speciosus (Lindl.) var. macranthus (Nutt.) Cronq.	Forb	Perennial
Gnaphalium palustre Nutt.	Forb	Annual
Gutierrezia sarothrae (Pursh.) Britt. & Rushby.	Half-shrub	Perennial
Helianthella uniflora (Nutt.) Torr. & Gray.	Forb	Perennial
Senecio integerrimus Nutt.	Forb	Perennial
Senecio pauperculus Michx. var. Thomsoniensis (Greenm.) Boiv.	Forb	Perennial
Senecio serra Hook.	Forb	Perennial
Solidago canadensis L. var. salebrosa (Piper) M. E. Jones [S. lepida DC.]	Forb	Perennial
Sonchus arvensis L.	Forb	Perennial
*Taraxacum officinale Weber.	Forb	Perennial
*Tragopogon porrifolius L.	Forb	Perennial
CRUCIFERAE		
Arabis drummondii A. Gray.	Forb	Perennial

APPENDIX I (Continued).

Species	Life Form	Longevity
Arabis glabra (L.) Bernh.	Forb	Perennial
Brassica campestris L.	Forb	Annual to Perennial
*Thlaspi arvense L.	Forb	Annual
CYPERACEAE		
Carex spp.	Sedge	Perennial
Eleocharis macrostachya Britton.	Sedge	Perennial
FUMARIACEAE		
Corydalis aurea Willd.	Forb	Perennial
GENTIANACEAE		
Frasera speciosa Dougl. [Swertia radiata (kellogg) Kuntze.].	Forb	Perennial or Biennial
GERANIACEAE		
Geranium viscosissimum Rydb.	Forb	Perennial
Geranium richardsonii Fisch. & Trautv.	Forb	Perennial
GRAMINEAE		
Agropyron albicans Scribn. & Smith.	Grass	Perennial
Agropyron trachycaulum (Link) Malte.	Grass	Perennial
Agrostis scabra Willd. var. Geminata (Trin.) Swallen.	Grass	Perennial
Bromus carinatus Hook & Arn.	Grass	Annual
Bromus ciliatus L.	Grass	Perennial
Calamagrostis koelerioides Vasey.	Grass	Perennial
Calamagrostis rubescens Buckl.	Grass	Perennial
Elymus cinereus Scribn. & Merr.	Grass	Perennial
Festuca idahoensis Elmer.	Grass	Annual
Koeleria cristata (L.) Pers.	Grass	Perennial
Melica spectabilis Scribn.	Grass	Perennial
Orysopis Hymenoides (Roem. & Schult.) Ricker	Grass	Perennial
Phleum pratense L.	Grass	Perennial

APPENDIX I (Continued).

Species	Life Form	Longevity
Poa ampla Merr.	Grass	Perennial
Poa canbyi (Scribn.) Piper.	Grass	Perennial
Poa fendleriana (Stud.) Vasey.	Grass	Perennial
Poa nervosa (Hook.) Vasey.	Grass	Perennial
*Poa pratensis L.	Grass	Perennial
Stipa columbiana Macoun.	Grass	Perennial
Stipa comata Trin. & Rupr.	Grass	Perennial
HYDROPHYLLACEAE		
Hydrophyllum capitatum Dougl.	Forb	Perennial
Nemophila breviflora A. Gray.	Forb	Annual
Phacelia franklinii Pursh.	Forb	Biennial or Perennial
JUNCACEAE		
Juncus confusus Cov.	Sedge-like	Perennial
LEGUMINOSAE		
Astragalus miser Dougl. var. Hylophilus (Rydb.) Barneby.	Forb	Perennial
Hedysarum boreale Nutt. var. Boreale.	Forb	Perennial
Lupinus argenteus Pursh. ssp. parviflorus (Nutt.) Phillips.	Forb	Perennial
Lupinus sericeus Pursh.	Forb	Perennial
LILACEAE		
Fritillaria atropurpurea Nutt.	Forb	Perennial
Fritillaria pudica (Pursh.) Spreng.	Forb	Perennial
LINACEAE		
Linum lewisii Pursh.	Forb	Perennial
LOASACEAE		
Mentzelia dispersa S. Watson.	Forb	Annual

APPENDIX I (Continued).

Species	Life Form	Longevity
MALVACEAE		
Iliamna rivularis (Dougl.) Greene var. Diversa (A. Nels.) C. L. Hitche. [Sphaeralcea rivularis (Dougl.) Torr.].	Forb	Perennial
ONAGRACEAE		
Epilobium adenocaulon Hausskn.	Forb	Perennial
Epilobium angustifolium L.	Forb	Perennial
Gayophytum nuttallii Torr. & Gray [C. diffusum T. & G. subsp. parviflorum Lewis & Sweykowski].	Forb	Annual
Oenothera heterantha Nutt.	Forb	Perennial
PINACEAE		
Picea engelmannii Parry.	Tree	Perennial
Pseudotsuga menziesii (Mirb.) Franco.	Tree	Perennial
POLEMONIACEAE		
Collomia linearis Nutt.	Forb	Annual
Gilia aggregata (Pursh.) Spreng.	Forb	Perennial
Phlox multiflora A. Nels.	Forb	Perennial
POLYGONACEAE		
Eriogonum umbellatum Torr. var. Subalpinum (Greene) M. E. Jones	Forb	Perennial
Polygonum douglasii Greene.	Forb	Annual
Polygonum kelloggii Greene.	Forb	Annual
Rumex paucifolius Nutt.	Forb	Perennial
PORTULACAEAE		
Claytonia lanceolata Pursh.	Forb	Perennial
PRIMULACEAE		
Androsace septentrionalis L. var. Subumbellata A. Nelson.	Forb	Annual
Dodecatheon conjugens Greene.	Forb	Perennial

APPENDIX I (Continued).

Species	Life Form	Longevity
RANUNCULACEAE		
Clematis hirsutissima Pursh.	Forb	Perennial
Delphinium nelsoni Greene.	Forb	Perennial
Delphinium occidentale (S. Wats.) S. Watson.	Forb	Perennial
Ranunculus jovis A. Nelson.	Forb	Perennial
Thalictrum fendleri Engelm.	Forb	Perennial
ROSACEAE		
Amelanchier alnifolia Nutt.	Shrub	Perennial
Fragaria virginiana Duchn. var. Glauca S. Wats. [F. glauca Rydb.].	Forb	Perennial
Geum triflorum Pursh. var. Ciliatum (Pursh.) Fassett.	Forb	Perennial
Potentilla arguta Pursh. spp. convallaria (Rydb.) Th. Wolf.	Forb	Perennial
Potentilla fruiticosa L.	Shrub	Annual
Potentilla gracilis Dougl. ssp. nuttallii (Lehm.) Keck.	Forb	Perennial
Prunus virginiana L. var. Melanocarpa (A. Nels.) Sarg.	Shrub	Perennial
Purshia tridentata (Pursh.) DC.	Shrub	Perennial
Rosa woodsii Lindl.	Shrub	Perennial
RUBIACEAE		
Galium boreale L.	Forb	Perennial
SALIACEAE		
Populus tremuloides Michx.	Tree	Perennial
SANTAIACEAE		
Comandra pallida A. DC. [C. umbellata (L.) Nutt.].	Forb	Perennial
SAXIFRAGACEAE		
Heuchera parviflora Nutt. var. Utahensis (Rydb.) Garrett.	Forb	Perennial

APPENDIX I (Continued).

Species	Life Form	Longevity
Lithophragma bulbifera Rydb.	Forb	Perennial
Ribes inerme Rydb.	Shrub	Perennial
Saxifraga rhomboidea Greene var. Rhomboidea	Forb	Perennial
SCROPHULARIACEAE		
Castilleja miniata Dougl.	Forb	Perennial
Castilleja pilosa (S. Wats.) Rydb. [*C. longispica* A. Nels.].	Forb	Perennial
Collinsia parviflora Dougl.	Forb	Annual
Penstemon procerus Dougl.	Forb	Perennial
Penstamon strictus Rydb.	Forb	Perennial
UMBELLIFERAE		
Perideridia gairdneri (Hook. & Arn.) Mathias.	Forb	Perennial
Lomatium simplex (Nutt.) Macbr.	Forb	Perennial
VALERIANACEAE		
Valeriana edulus Nutt.	Forb	Perennial
VIOLACEAE		
Viola praemorsa Doug. ssp. linguaefolia (Nutt.) Baker & Clausen [*V. nuttallii* Pursh.].	Forb	Perennial

* = Naturalized species.

APPENDIX II

Soil properties of the Burro Hill study areas in 1975 and 1976. Values are means from samples taken in late June of each year (N = 3 on Spring Burn; N = 12 on Fall Burn; N = 4 on Unburned-Control). Each sample was a composite from the upper 20 cm. Analysis was done by Agricultural Consultants Laboratory, Brighton, Colorado 80601[a].

Study Area	Year	Texture	Cation Exchange Capacity (Meq/100 g)	% Organic Matter	pH	Organic Matter Nitrogen (lbs)	Nutrient Concentrations (ppm)			
							P	K	C_a	Mg
Spring Burn	1975	Silty loam	15.0	5 +[b]	6.35	78	30.5	375	1750	205
	1976	Silty loam	13.5	1.8	6.9	70	29.0	395	1750	113
Fall Burn	1975	Silty loam	15.5	3.9 +	6.6	66	31.2	417	1785	255
	1976	Silty loam	16.8	1.8	6.6	71	20.7	370	2185	142
Unburned-Control	1975	Silty loam	15.5	5 +	6.1	72	20.5	333	1850	243
	1976	Silty loam	15.8	1.7	6.6	67	10.5	335	2075	128

[a]Analytical Methods: Texture - Hydrometer
pH - Electrometric (probe)
Organic matter - acid chromate digestion
Phosphorus - sodium bicarb/Mo blue (ascorbic acid)
Ca, Mg, K - ammonium acetate extraction/atomic absorbtion spectrometry
Organic matter nitrogen - calculated release
Cation exchange capacity - sum of cations method.

[b]'+' indicates value is higher than stated, although exact range is unknown since analysis results ranged from 0 to 5 +.

APPENDIX III

Dominance (percent cover) and frequency of occurrence in parentheses, of shrubs, grasses and forbs on Burro Hill study areas in 1974-1976. Values are means for six sampling dates throughout growing seasons, - = not present in sampling plots, T = present on transect but < 1% shrub cover.

Species[1]		Spring Burn			Fall Burn			Unburned-Control		
		1974	1975	1976	1974	1975	1976	1974	1975	1976
SHRUBS										
Artemisia tridentata	live	2(18)	2(20)	4(28)	33(33)	--	T(3)	37(100)	38(100)	36(100)
	dead	5(80)	5(75)	3(88)	T(5)	T(3)	T(5)	T(5)	T(10)	T(3)
Symphoricarpus oreophilus		1(20)	4(35)	4(23)	12(50)	1(10)	5(28)	9(50)	8(43)	10(55)
Rosa woodsii		1(25)	1(30)	3(10)	1(8)	1(28)	3(35)	2(15)	1(13)	1(10)
Berberis repens		T(3)	1(5)	T(5)	T(3)	--	1(10)	--	T(3)	--
Chrysothamnus nauseosus		T(10)	1(15)	2(33)	T(5)	--	--	--	--	--
Totals[2]		10	15	19	48	3	9	50	49	48
GRASSES										
Agropyron albicans		0.7(10)	2.1(9)	1.1(10)	2.0(20)	--	2.1(11)	1.0(10)	1.2(20)	1.7(16)
Agropyron trachycaulum		0.1(1)	--	0.3(2)	0.2(3)	--	0.9(8)	--	0.1(3)	--
Bromus ciliatus		--	--	0.2(5)	0.1(1)	--	0.5(4)	0.1(3)	0.1(3)	0.1(3)
Calamagrostis rubescens		0.1(1)	0.1(1)	--	0.1(1)	--	--	--	0.3(3)	0.9(2)
Carex spp.		0.6(10)	0.9(5)	2.7(17)	1.4(12)	0.5(10)	1.1(9)	0.5(5)	1.1(15)	0.8(12)
Festuca idahoensis		3.1(39)	4.0(40)	5.3(28)	24.1(80)	0.1(5)	0.7(6)	18.0(70)	21.2(75)	17.2(64)
Koeleria cristata		0.2(1)	--	--	--	--	0.2(1)	--	--	--
Melica spectabilis		0.1(5)	0.2(7)	1.3(15)	0.3(20)	0.1(1)	0.2(3)	1.0(20)	1.0(25)	1.0(20)
Poa ampla		3.0(25)	3.1(30)	4.0(26)	1.7(22)	2.1(15)	2.1(14)	2.0(20)	2.0(15)	2.3(31)

APPENDIX III (Continued).

Species[1]	Spring Burn			Fall Burn			Unburned-Control		
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Poa nervosa	1.2(5)	1.5(10)	1.3(9)	0.3(2)	0.9(2)	2.3(10)	0.1(3)	0.9(5)	0.1(3)
Poa pratensis	--	0.4(5)	--	0.1(1)	0.1(2)	--	0.1(1)	0.1(2)	--
Stipa columbiana	5.2(35)	6.7(20)	5.1(32)	3.0(30)	1.8(7)	4.7(22)	4.0(35)	2.1(20)	3.9(28)
Stipa comata	0.1(1)	0.2(1)	0.2(4)	--	--	--	--	--	--
Totals[2]	14.4	19.3	21.6	33.4	5.9	15.0	26.9	30.1	28.0
FORBS									
Achillea millefolium	2.0(35)	2.3(30)	2.5(41)	1.6(40)	0.2(1)	4.4(17)	1.0(49)	1.5(45)	1.7(41)
Agoseris glauca	--	--	0.4(10)	0.2(1)	--	--	0.1(2)	0.2(2)	0.2(4)
Androsace septentrionalis	--	--	--	--	--	0.2(3)	--	--	--
Arabis glabra	--	--	--	0.1(5)	--	--	--	--	0.1(4)
Arenaria congesta	0.3(10)	0.2(10)	0.4(11)	2.3(31)	--	0.1(4)	2.0(25)	1.8(15)	2.7(24)
Aster perelegens	0.3(10)	0.6(10)	0.5(6)	0.5(20)	0.1(1)	0.3(4)	0.1(3)	0.4(10)	0.6(15)
Astragalus miser	0.6(3)	0.6(5)	0.8(7)	1.3(21)	--	0.2(4)	1.0(15)	1.0(20)	1.3(17)
Chenopodium atrovirens	0.3(31)	0.1(10)	0.1(4)	--	3.1(25)	5.7(38)	--	--	--
Claytonia lanceolata	0.2(20)	0.2(2)	0.2(5)	0.3(11)	--	0.1(3)	0.2(3)	0.3(10)	0.2(5)
Clematis hirsutissima	--	--	--	0.6(5)	--	--	0.3(5)	0.5(10)	0.2(5)
Collinsia parviflora	0.6(10)	0.2(2)	--	0.9(16)	--	--	1.0(16)	1.7(20)	1.6(16)
Collomia linearis	3.0(25)	3.1(29)	4.2(27)	2.8(16)	0.1(1)	0.3(4)	2.1(10)	2.1(15)	3.7(27)
Cirsium vulgare	0.5(3)	0.8(5)	0.9(8)	--	0.2(1)	0.4(3)	0.1(1)	0.2(10)	0.3(7)
Epilobium angustifolium	0.3(1)	0.2(2)	0.1(2)	--	0.9(15)	3.9(8)	--	--	--

APPENDIX III (Continued).

Species[1]	Spring Burn			Fall Burn			Unburned-Control		
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Erigeron speciosus	--	0.2(1)	--	0.2(5)	--	0.8(2)	0.4(5)	0.3(6)	0.4(4)
Eriogonum umbellatum	0.1(3)	0.2(6)	1.3(14)	3.6(20)	--	0.5(4)	3.0(20)	3.1(15)	4.2(23)
Fragaria virginiana	0.1(3)	1.3(2)	0.9(6)	2.0(20)	--	0.1(1)	1.0(10)	1.0(10)	0.7(8)
Galium boreale	0.1(2)	0.2(1)	0.3(3)	0.1(3)	--	1.6(9)	--	0.2(3)	0.1(3)
Gayophytum nuttallii	--	0.1(2)	--	--	--	0.8(2)	--	--	--
Geranium viscosissimum	3.1(5)	5.2(15)	5.2(27)	8.3(30)	1.1(5)	2.2(12)	6.1(20)	6.2(28)	7.0(39)
Geum triflorum	--	0.2(1)	--	0.3(10)	--	--	1.0(10)	1.2(10)	1.8(25)
Helianthela uniflora	2.1(2)	1.7(7)	0.7(4)	0.1(2)	--	1.0(7)	0.3(5)	0.1(3)	--
Iliamna rivularis	0.9(2)	0.3(1)	--	--	1.0(1)	2.3(5)	--	--	--
Lapula floribunda	--	--	0.1(1)	--	--	--	--	--	--
Lithospermum ruderale	0.3(1)	--	0.6(5)	0.1(1)	--	0.4(1)	--	0.1(1)	--
Lupinus sericeus	6.1(30)	9.8(45)	7.2(47)	4.1(35)	7.1(7)	16.5(51)	3.1(35)	3.4(40)	4.3(31)
Penstamon procerus	--	0.2(1)	--	--	--	0.2(1)	--	--	--
Perideridia gairdneri	0.1(2)	0.1(2)	0.5(14)	1.7(26)	--	--	1.0(5)	1.5(25)	1.1(22)
Potentilla arguta	--	--	0.1(1)	--	--	--	--	0.4(1)	0.7(3)
Potentilla gracilis	0.7(3)	0.6(3)	1.1(8)	3.1(21)	0.3(5)	1.3(7)	2.2(10)	2.4(12)	2.7(19)
Rumex paucifolius	0.9(1)	1.0(5)	0.6(9)	0.5(5)	0.1(1)	0.1(2)	0.2(5)	0.3(2)	0.4(4)
Senecio integerrimus	1.0(1)	1.0(3)	1.0(11)	1.0(12)	--	0.2(1)	0.6(2)	0.7(7)	0.4(1)
Taraxacum officinale	1.0(2)	0.9(5)	0.9(11)	4.1(3)	0.1(1)	0.2(4)	3.0(25)	3.7(33)	3.6(28)
Totals[2]	25.8	32.0	31.2	40.1	14.9	44.3	30.4	34.6	40.5

APPENDIX III (Continued).

Species[1]	Spring Burn			Fall Burn			Unburned-Control		
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Litter	10.7(85)	29.2(100)	33.7(100)	50.0(100)	0.5(4)	7.3(43)	55.6(100)	60.3(100)	52.7(100)
Bare Ground	53.7(90)	15.7(61)	9.3(39)	12.1(39)	80.2(100)	26.0(73)	9.2(45)	11.1(51)	10.9(44)
Rock	1.2(10)	0.6(10)	0.3(8)	0.3(9)	0.5(15)	0.9(13)	0.9(10)	0.9(10)	0.7(11)

[1]Species tabulated are those with a mean coverage > 0.1% and frequency of occurrence > 1%. Additional species sampled all had mean coverage < 0.1% and frequency of occurrence < 1% in all years on all areas (Amelanchia alnifolia, Antennaria rosea, Arnica sororia, Brassica campestris, Campanulla rotundifolia, Castilleja pilosa, Chenopodium overi, Comandra pallida, Delphinium nelsoni, Dodecatheon conjugens, Elymus cinereus, Hackelia floribunda, Heurcha parviflora, Hydrophyllum capitatum, Juncus confusus, Linum lewisii, Nemophila breviflora, Phleum pratense, Phlox multiflora, Poa fendleriana, Potentilla fruticosa, Prunus virginiana, Purshia tridentata, Ribes inerme, Viola praemorsa).

[2]Totals include those species with < 0.1% coverage (listed above).

APPENDIX IV

Bird species observed on Burro Hill study areas in 1974-1976. Species listed are those with ≥ 5 sightings over entire study period. Nomenclature follows A.O.U. checklist (1957).

Red-tailed Hawk	*Buteo jamaicensis*
Swainson's Hawk	*Buteo swainsoni*
Marsh Hawk	*Circus dyaneus*
Sparrow Hawk	*Falco sparverius*
Blue Grouse	*Dendragapus obscurus*
Sandhill Crane	*Grus canadensis*
Mourning Dove	*Zenaidura macroura*
Common Flicker	*Colaptes auratus*
Hairy Woodpecker	*Dendrocopus villosus*
Tree Swallow	*Tridoprocne bicolor*
Barn Swallow	*Hirundo rustica*
American Robin	*Turdus migratorius*
Mountain Bluebird	*Sialia currucoides*
Yellow-rumped Warbler	*Dendroica coronata*
Western Meadowlark	*Sturnella neglecta*
Brewer's Blackbird	*Euphagus cyanocephalus*
Western Tanager	*Piranga ludoviciana*
Pine Siskin	*Spinus pinus*
Green-tailed Towhee	*Chlorura chlorura*
Vesper Sparrow	*Pooecetes gramineus*
Dark-eyed Junco	*Junco hyemalis*
Chipping Sparrow	*Spizella passerina*
Brewer's Sparrow	*Spizella breweri*
White-crowned Sparrow	*Zonotrichia leucophrys*

SECTION IV

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BIBLIOGRAPHY

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